

**VOLUME I****AIRPLANE SPECIFICATION FOR  
NORTHROP N-309 NASA V/STOL  
JET OPERATIONS RESEARCH AIRPLANE**

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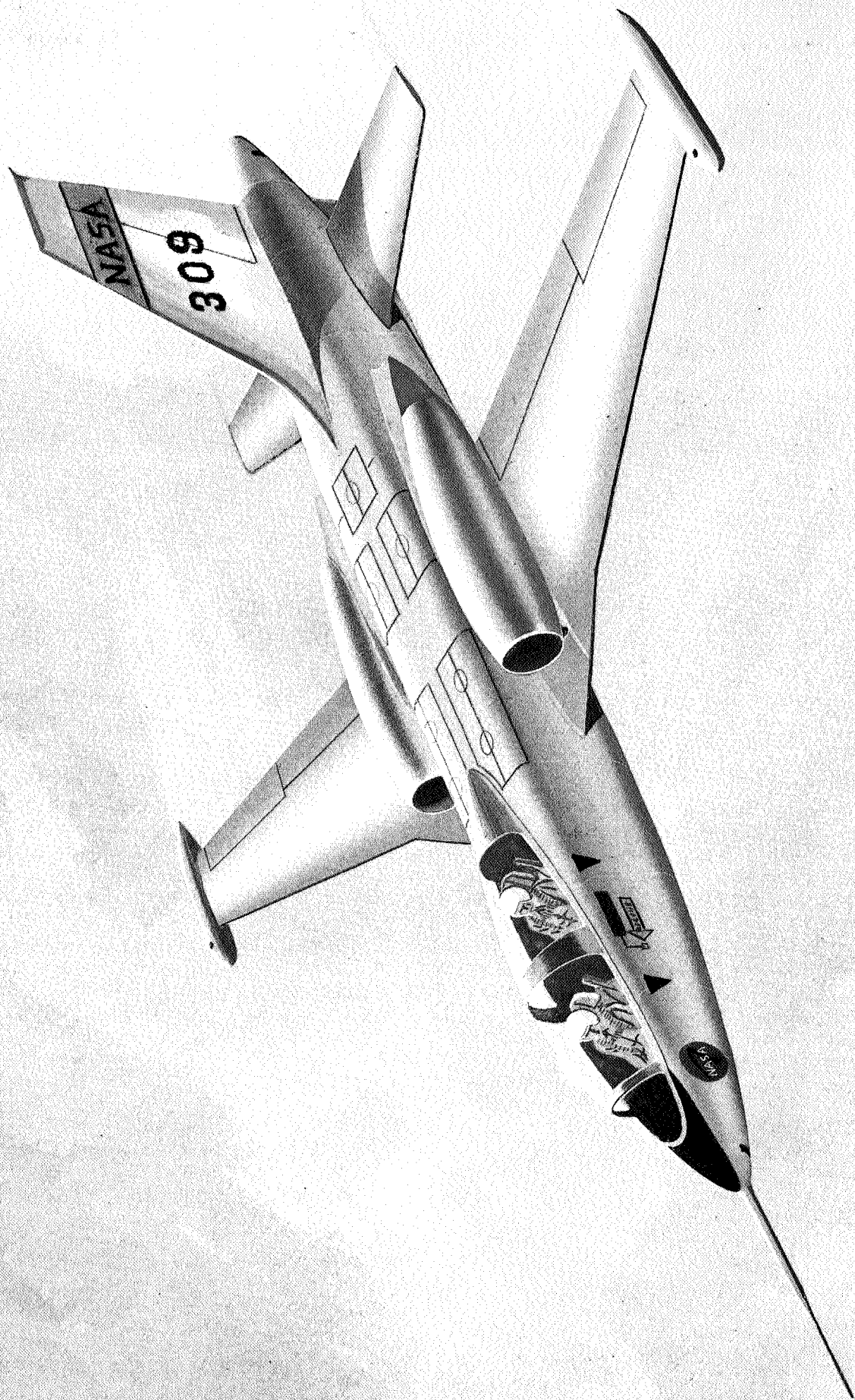
3 AIRCRAFT PRELIMINARY DESIGN REPORT V/STOL  
JET OPERATIONS RESEARCH AIRPLANE DESIGN  
STUDY - VOLUME I - AIRPLANE SPECIFICATION  
FOR NORTHROP N-309 NASA V/STOL JET  
OPERATIONS RESEARCH AIRPLANE 1

Prepared for

National Aeronautics and Space Administration  
Langley Research Center  
Langley Station  
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(Contract NAS1-6777)

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### ABSTRACT

This study is presented in three volumes:

Volume I— Airplane Specification for Northrop N-309 NASA V/STOL Jet Operations Research Airplane (NASA CR-66417)

Volume 11— Airplane Specification for Northrop Modified T-39A NASA V/STOL Jet Operations Research Airplane (NASA CR-66418)

Volume 111— Substantiating Technical Data (NASA CR-66419)

These reports provide a preliminary design description of a new and modified V/STOL jet operations research airplane. This preliminary design was conducted by Northrop Norair during Part III of Contract NAS1-6777, "Jet V/STOL Operations Research Airplane Design Study."

## 1.0 SCOPE

This specification covers the following airplane:

Type - Multi-engine, V/STOL research landplane

Designer's Name and Model Designation - Northrop Corporation -  
Norair Division

Model number N-309

Number of Places for Active Crew -

Two place, tandem, one evaluation and one safety pilot station

Number and Kind of Engines -

All engines are modified YJ85-19 General Electric Turbojets

Composite lift hovering mode: seven lifting engines  
plus two lift-cruise engines

Direct lift hovering mode: eight lifting engines plus  
two cruise engines.

### 1.1 MISSION

The mission of the aircraft is to conduct research and gather engineering data on the performance and stability and control characteristics needed by fighter-type V/STOL configurations in the hovering and transition speed range. This research is to be conducted by NASA with possible Air Force participation. The aircraft is capable of utilizing a mixed propulsion system (lift-only plus lift-cruise engines) to conduct flight research either with all engines lifting or with separate lifting and cruising engines. The most important flight regime for the purpose of these tests is the final instrument approach to a small VTOL site under simulated minimum weather conditions and the transition (including conversion) from conventional flight to hover or hover to conventional flight. Therefore, no supersonic capability is provided. Control at speeds below those where the aerodynamic controls are effective is obtained with a reaction control system using engine bleed air. The aircraft is to be capable of vertical takeoff and landing under the specified altitude and temperature and specified thrust to weight ratios.

It shall also be capable of short and conventional takeoff and landing operations from prepared runways.

## 1.2 DRAWING AND SPECIFICATION PREPARATION

Experimental type, engineering drawings shall be prepared by the contractor for the design, fabrication, assembly and installation programs for the test aircraft. MIL-D-70327 specification is to be used for guidance by the Contractor, but shall not require official or unofficial request and approval of deviations thereto. Quality of original drawings shall be sufficient to provide satisfactory blueprint as diazo process prints.

Specifications will be processed through a project control group to assure consistent design requirements, sufficient reliability consideration, meeting of schedules, uniformity of presentation, and minimum cost.

The contractual airplane specifications, subsystem specifications and data requirements will be issued formally six months after initial contract with the concurrence of NASA. During this period, a Project Data Manual will be issued to formalize policy, major design decisions and special directives. The availability of this type information to project personnel has been of especially high benefits on previous projects. Specifications for those subsystems of a developmental nature will be detailed as design progresses and will be included in the Project Data Manual.

Component specifications for items to be designed by vendors or subcontractors will be prepared consistent with program objectives through the project control group. As the major components and final assemblies are released for purchase, the necessary test specifications, receiving inspection instructions, evaluation criteria, and various inspection instructions through assembly, installation, and flight proofing and acceptance will be initiated.

The Specification Change Notice (SCN) method will be used to keep information up to date on all specifications requiring NASA approval. The method shows changes to specific pages and all previously-approved changes, which coordinates all changes and informs all personnel of the total effect of successive revisions to the specification.

## 2.0 APPLICABLE DOCUMENTS

### 2.1 COMPONENT MANUFACTURERS SPECIFICATION

The lift and propulsion engines are YJ85-19 General Electric turbojets with performances as specified in General Electric Engine Specification No. E1129, dated 1 November 1966. The stability augmentation system and variable stability equipment will be in accordance with the specifications prepared by Northrop Corporation as shown in Appendix 111.

Publications listed in 2.3 form a part of this specification insofar as their requirements are applicable to the development of the aircraft. These documents shall be applicable only as guides in the design of the flight research vehicle except where the requirements of such documents directly affect flight or safety. The latter shall be complied with as modified by deviations contained in Appendix II of this specification. The effective issue date for Government specifications and publications not specifically listed herein and considered essential to those airplanes shall be as shown in the Department of Defense "Index of Specifications and Standards", dated 1 November 1960, and any cumulative subsequent supplements.

### 2.2 CONTRACTOR PUBLICATIONS

The Contractor, at its option, may elect to comply with (a) any new specification or (b) a revision to an existing specification issued subsequent to the date shown for the previously listed issue.

### 2.3 MILITARY SPECIFICATIONS

MIL-HDBK-5	Metallic Materials and Elements for Flight Vehicle Structures
MIL-A-8806	Table II and Table III, Acoustical Noise Level in Aircraft
MIL-A-8860 (ASG) through MIL-A-8870 (ASG)	Series, Airplane <b>Strength</b> and Rigidity, General Specifications for
ARDCM 80-1	Handbook of Instructions for Aircraft Design
MIL-STD-805	Towing, Fittings and Provisions for Fixed <b>Wing</b> Aircraft, Design Requirements for

MIL-STD-809	Adaptor, Aircraft Jacking Point, Design and Installation of
MIL-S-8698 (ASG)	Structural Design Requirements, Helicopters
MIL-W-25140 (ASG)	Military Specifications, Weight and Balance Control Data (For Airplanes and Rotorcraft)
MIL-P-8184	Plastic Sheet, Acrylic, Modified
MIL-S-7811	Sandwich Construction, Aluminum Alloy Faces, Aluminum Foil Honeycomb Core
MIL-C-8073A-1	Core Material, Plastic Honeycomb, Laminated Glass Fabric Base, for Aircraft Structural Applications
MIL-C-7438C-2	Core Material, Aluminum, for Sandwich Construction
MIL-F-7179A	Finishes and Coating, General Specification for Protection of Aircraft and Aircraft Parts
MIL-R-7705A	Radomes
MIL-C-5011A	Standard Aircraft Characteristics and Performance
MIL-W-5013E	Wheel and Brake Assemblies, Aircraft
MIL-C-5015E	Connectors, Electrical
MIL-W-5088B	Wiring, Aircraft, Installation of
MIL-P-5238A	Pump, Fuel Booster, Aircraft, General Specification
MIL-E-5400A	Electronic Equipment, Airborne, General Specification
MIL-H-5440B	Hydraulic Systems: Design, Installation and Tests
MIL-H-5606	Hydraulic Fluid Petroleum Base
MIL-L-5667A	Lighting Equipment, Aircraft Instrument Panel, General Specification, Installation of
MIL-C-5809B	Circuit Breakers, Trip Free, Aircraft
MIL-I-5997A	Instruments and Instrument Panels, Aircraft, Installation
MIL-T-6053A	Impact Shock Absorber, Landing Gear Aircraft
MIL-R-6106B	Relays, Electric, Aircraft
MIL-G-6641A	Gearbox Aircraft Accessory Drive, General Specification
MIL-S-6745	Switches, Aircraft Toggle
MIL-L-6880B	Lubrication of Aircraft, General Specification
MIL-D-7006A	Detecting Systems: Fire, Aircraft Installation
MIL-E-007016B	Electrical Load Analysis: Alternating Current
MIL-E-7080A	Electrical Equipment Installation, General Specification
MIL-D-7188	Compasses, Pilot's Standby, Installation
MIL-C-7244B	Cap and Adapter Unit, Tank Filler
MIL-S-7470	Shaft, Power Transmission Aircraft Accessory, General Specification

MIL-E-7614	Electrical Equipment, Alternating Current Aircraft, Installation, General Specification
MIL-A-7772B	Antenna Systems, Airborne: General Specification
MIL-P-7788	Plate, Plastic Cockpit and Interior Controls, Lighting
MIL-E-7894A	Electric Power, Aircraft Characteristics
MIL-M-7969A	Motors, Alternating Current, Aircraft, General Specification
MIL-A-8064	Actuators and Actuating Systems, Aircraft, Electro-Mechanical, General Requirement
MIL-I-8500A	Interchangeability and Replacement, Physical, of Component Parts for Aircraft
MIL-S-8552A	Strut, Aircraft Shock Absorber
MIL-B-8584B	Brake System, Wheel Aircraft, Design of
MIL-V-8608	Valves, Fuel Shut-off, Motor Operated
MIL-F-8615	Fuel System Components, General Specification
MIL-I-8700	Installation and Test of Electronic Equipment in Aircraft, General Specification
MIL-S-8710	Strainer, Fuel, General Specification
MIL-A-8730	Aircraft, General Specification
MIL-H-8775	Hydraulic System Components, Aircraft, General Specification
MIL-F-8785	Flying Qualities of Piloted Aircraft
MIL-S-9479	Seat, Upward Ejection, Aircraft
MIL-F-9490B	Flight Control Systems, Design Installation and Test of, General Requirements for
MIL-Q-9858	Quality Control System Requirements
MIL-C-18244A	Control and Stabilization Systems, Automatic, Piloted Aircraft, General Specification
MIL-STD-810	Environmental Test Methods for Aerospace and Ground Equipment
AFSCM-80-6	Handbook of Instructions for Aerospace Ground Equipment Design
AGARD-408	Recommendations for V/STOL Handling Qualities Modified Per NASA (NAS1-6777)

### 3.0 REQUIREMENTS

#### 3.1 CHARACTERISTICS

##### 3.1.1 Three View Drawing

The general arrangement of the vehicle shall be in accordance with the three view drawing AD4486, Figure 3-1.

##### 3.1.2 Flight Performance

Performance of the airplane is summarized in accordance with requirements specified in NASA Request for Proposal L-7151, "V/STOL Jet Operations Research Airplane Design Study". Both design and supplemental performance are presented in compliance with requirements and overall aircraft capabilities.

3.1.2.1 DESIGN FLIGHT PERFORMANCE. The following design performance data are in accordance with NASA requirements specified in the RFP.

3.1.2.1.1 Design Hover Endurance. The fuel required to achieve a minimum design hover endurance of 12 minutes (15 minutes desired) shall be determined out of ground effect, with 50% of maximum control about all axes applied simultaneously, with a ratio of net hover lift to design gross weight of 1.00, and with specification fuel flows increased by 5% for the normal service tolerance. In addition, provisions for overload fuel, corresponding to one minute at hover power, shall be made to allow for warm up and check out on the ground before take-off. This fuel shall not be included in the design gross weight. Hover time is based on sea level 80°F conditions and composite flight. The design hover time for the above conditions, including estimated free air jet induced lift losses and weight contingencies, at a

Design Gross of 18,000 lb. (7 lift + 2 lift cruise engines) is 13.4 minutes.

3.1.2.1.2 Hover T/W Margins. With all engines operating and with 50 percent of maximum control about all axes applied simultaneously, the ratio of net hover lift to design gross weight shall not be less than 1.15 out of ground effect nor shall it be less



FIGURE 3-1

than 1.1 in ground effect. With 80 percent of the maximum control about the most critical axis and 50 percent about the other axes applied, the ratio of net hover lift to design gross weight shall not be less than 1.05 out of ground effect. The ratio of net hover lift to design gross weight shall not be less than 1.05 in ground effect for either of the above control applications. With the failure of any single engine, the net hover lift to design gross weight shall not be less than 1.05 (out of ground effect) using emergency ratings on the remaining engines. During this condition, the aircraft shall retain a margin of at least 20 percent of the maximum control moment available before the failure about the pitch and yaw axes, and 50 percent margin about the roll axis. Available and required thrust margins for the foregoing control conditions are tabulated below. Thrust-to-weight margins required are NASA levels plus estimated jet induced free air or ground effects. Available margins are airplane capabilities on a sea level 80°F day.

Engines Operating				Minimum Acceptable		Available	
	Pitch	Roll	Yaw	IGE	OGE	IGE	OGE
One Out	20	50	20	-	1.09	-	1.10
A11	80	50	50	1.20	-	1.24	-
A11	80	50	50	-	1.09	-	1.24
A11	50	50	50	1.20	-	1.24	-
A11	50	50	50	-	1.19	-	1.24

3.1.2.1.3 Transition Deceleration. The aircraft shall be capable of decelerating from  $1.2 V_{STALL}$  (power off) with approach flaps and gear down to hover in no more than 30 seconds. The constant altitude deceleration performance on Figure 3-2 shows airplane capabilities at  $\alpha=0^\circ$  and  $12^\circ$  at sea level and 80°F. Initial velocities are power on speeds with all engines lifting at idle thrust.

3.1.2.1.4 Conventional Flight Stall Speeds. To simulate overload STOL or VTOL flight, the aircraft shall be capable of the following speed requirements: at least a 40 knot power off stall speed spread from  $105 \pm 5$  knots to  $145 \pm 5$  knots. Clean and landing configuration stall speeds at design gross weight are indicated in the following table.

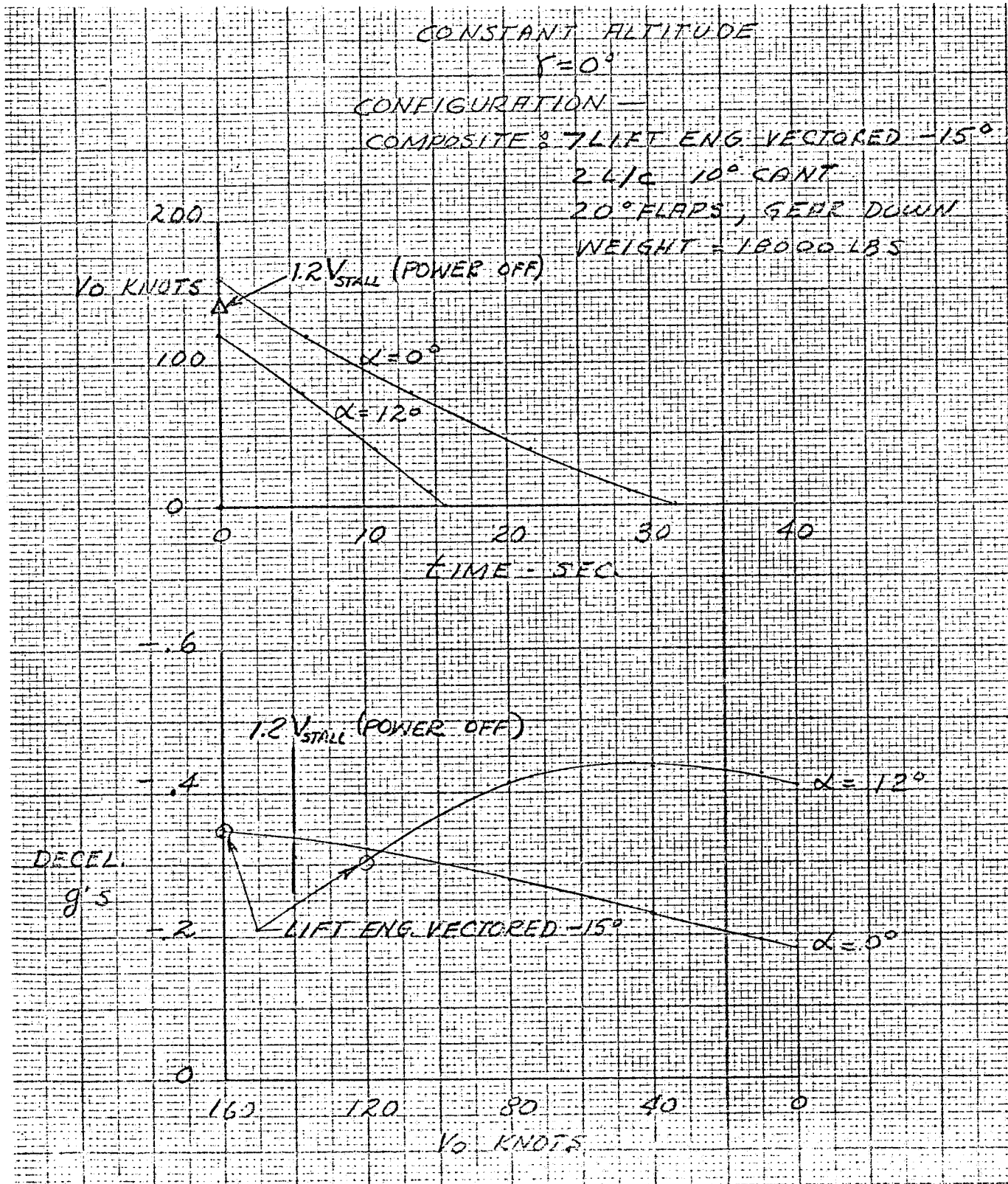


FIGURE 3-2. DECELERATION TRANSITION PERFORMANCE

Configuration	Ambient	Condition
	S.L. Std.	S.L., 80°F
Clean	149 kn	151 kn
Landing	108 kn	110 kn

**3.1.2.1.5 Level Flight Speed (One Engine Out).** The aircraft shall be able to continue conventional flight with the failure of a single cruise engine down to  $1.4 V_{STALL}$  (power off) with approach flaps, lift engine doors open and engines windmilling and with landing gear extended. In addition, the aircraft shall exhibit a positive rate of climb down to  $1.2 V_{STALL}$  (power off) upon retraction of the gear in the above configuration. Level flight thrust and drag versus speed in Figure 3-3 show the safe single engine speeds with gear retracted or extended and with or without lift engines windmilling.

**3.1.2.2 ADDITIONAL PERFORMANCE DATA.** The following additional performance data are provided to show overall airplane performance capabilities.

**3.1.2.2.1 Conventional Take-Off and Landing Performance.** Take-off and landing ground rolls and total distances to clear a 50 foot obstacle are presented in Figures 3-4 and 3-5 for varying gross weights on a ARDC sea level standard or sea level 80°F day. Take-offs are performed at military thrust with leading edge flaps at 25° and trailing edge flaps retracted. Landings reflect 25° leading edge flaps, 40° trailing edge flaps and idle thrust.

**3.1.2.2.2 Transition Acceleration.** Acceleration and time for transition is presented in Figure 3-6 for composite and direct lift operation at design take-off weight at military thrust on a sea level 80°F day. Composite acceleration is shown for 0° and 10° flight path angle and 0° for direct lift operation. Airplane configuration is with flaps and gear retracted.

**3.1.2.2.3 Rate of Climb.** Military thrust, instantaneous climb (constant velocity) versus altitude for three airplane weights from design gross to zero fuel weight are shown on Figure 3-7 for an ARDC standard atmosphere.

**3.1.2.2.4 Speed Altitude Summary.** The military thrust speed altitude envelope, for an ARDC standard day is shown for three airplane weights on Figure 3-8.

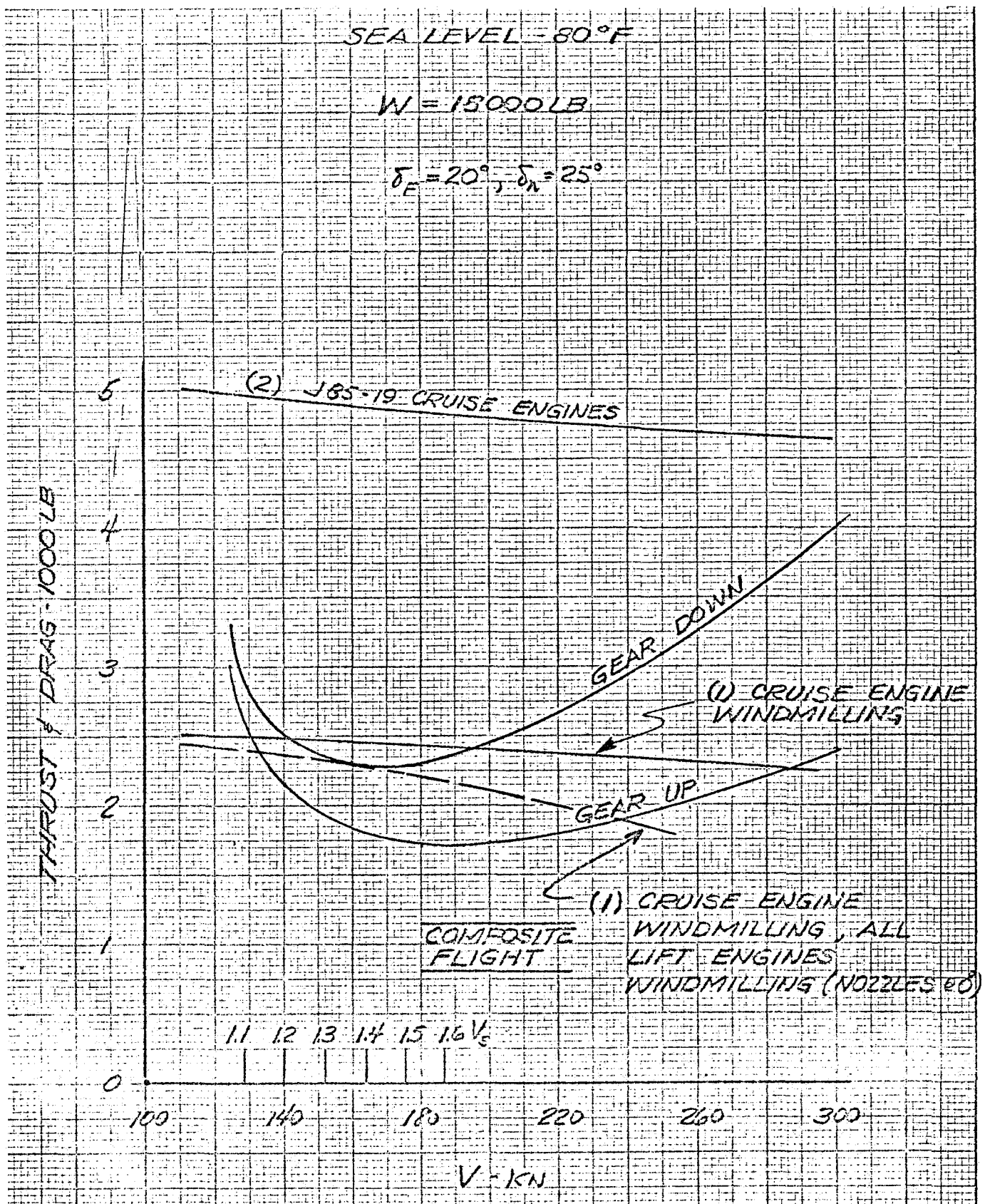


FIGURE 3-3. THRUST REQUIRED AND AVAILABLE

**3.1.2.2.5 Ferry Range Mission.** Ferry range for a constant altitude cruise at **36,089** feet is **702** N. M. including **84** N. M. for climb, with a full internal fuel load and research payload. The mission conforms to MIL-C-5011A rules and is defined as follows:

- (a) Take-off allowance **5** minutes of normal power.
- (b) Climb at military thrust to **36,089** feet.
- (c) Cruise at **36,089** feet @  $M = .7$ .
- (d) Landing reserve - twenty minutes at sea level at speed for maximum endurance plus five percent initial fuel. Fuel consumption increased by five percent for service tolerance.

**3.1.2.2.6 Transition Mission.** A typical transition mission that involves vertical take-offs and landings, transition acceleration and deceleration, and conventional climb and descent performance is outlined below.

- (a) Warm up and VTO (1 minute at hover thrust).
- (b) Transition at military thrust from  $V = 0$  to  $1.5 V_{STALL}$  (composite flight) and convert to level flight.
- (c) Accelerate to  $V_{climb}$  and climb to 25,000 feet at military thrust.
- (d) Descend to sea level at  $V = 300$  kn and decelerate to  $1.5 V_{STALL}$ .
- (e) Convert to VTOL configuration (composite) and decelerate to  $V = 0$ .
- (f) Land with five percent initial fuel for reserve plus fuel for twenty minutes loiter at sea level at speed for maximum endurance (MIL-C-5011A reserves).
- (a-f) Fuel consumption is increased by five percent for service tolerance (MIL-C-5011A).

With a full internal fuel load the airplane can complete three missions (a to e), landing the last time only.

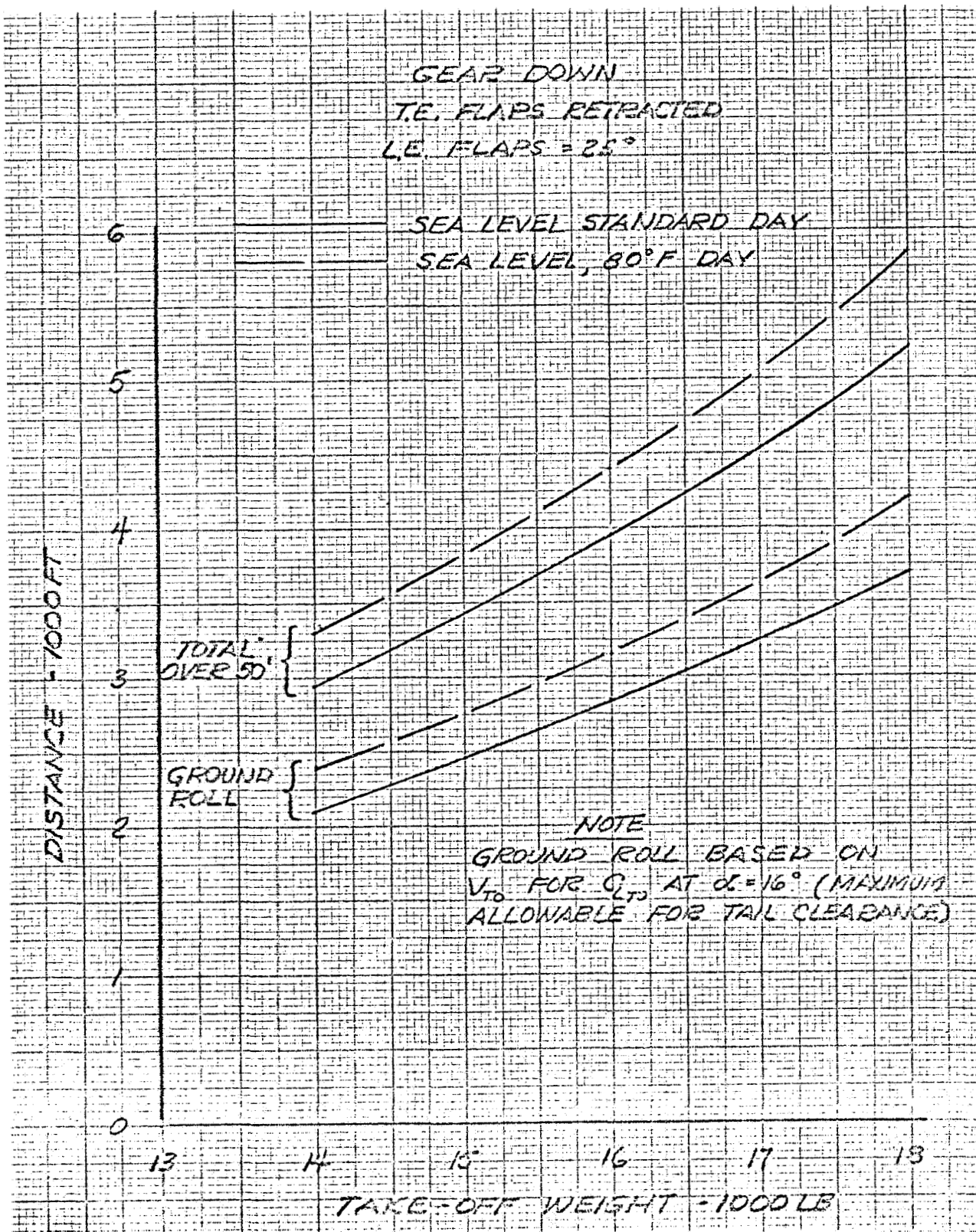


FIGURE 3-4. TAKE-OFF DISTANCE

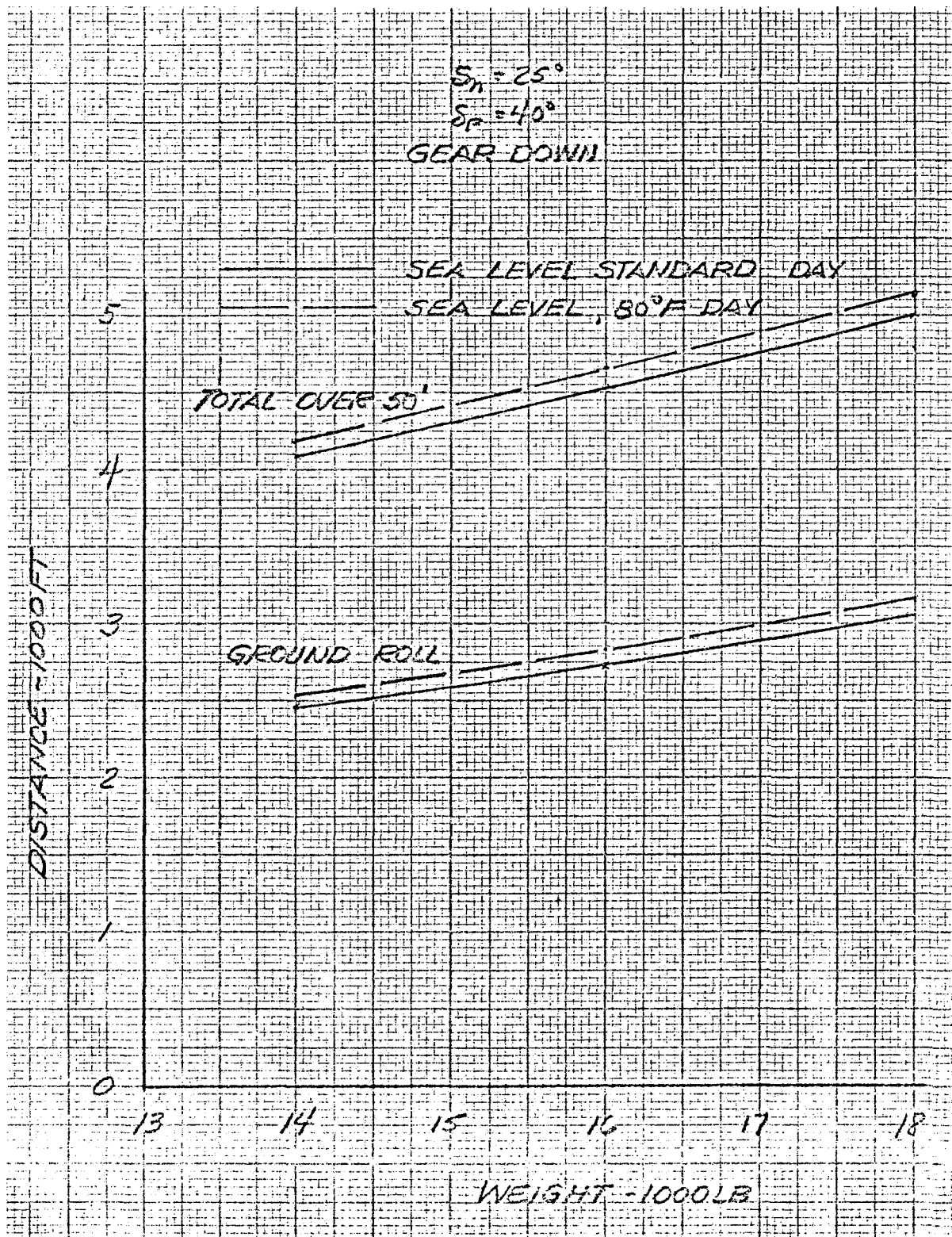


FIGURE 3-5. LANDING DISTANCE

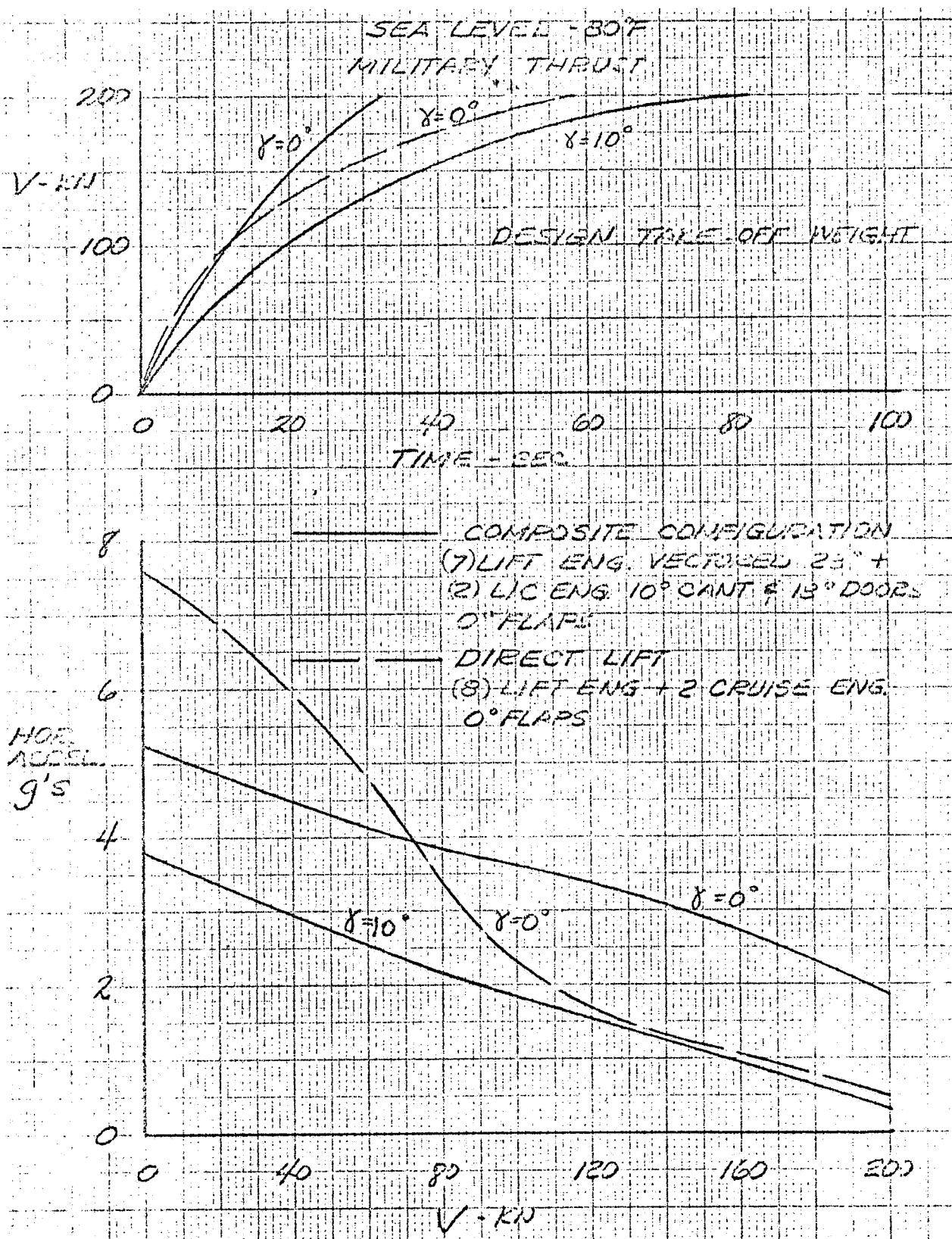


FIGURE 3-6. TRANSITION ACCELERATION

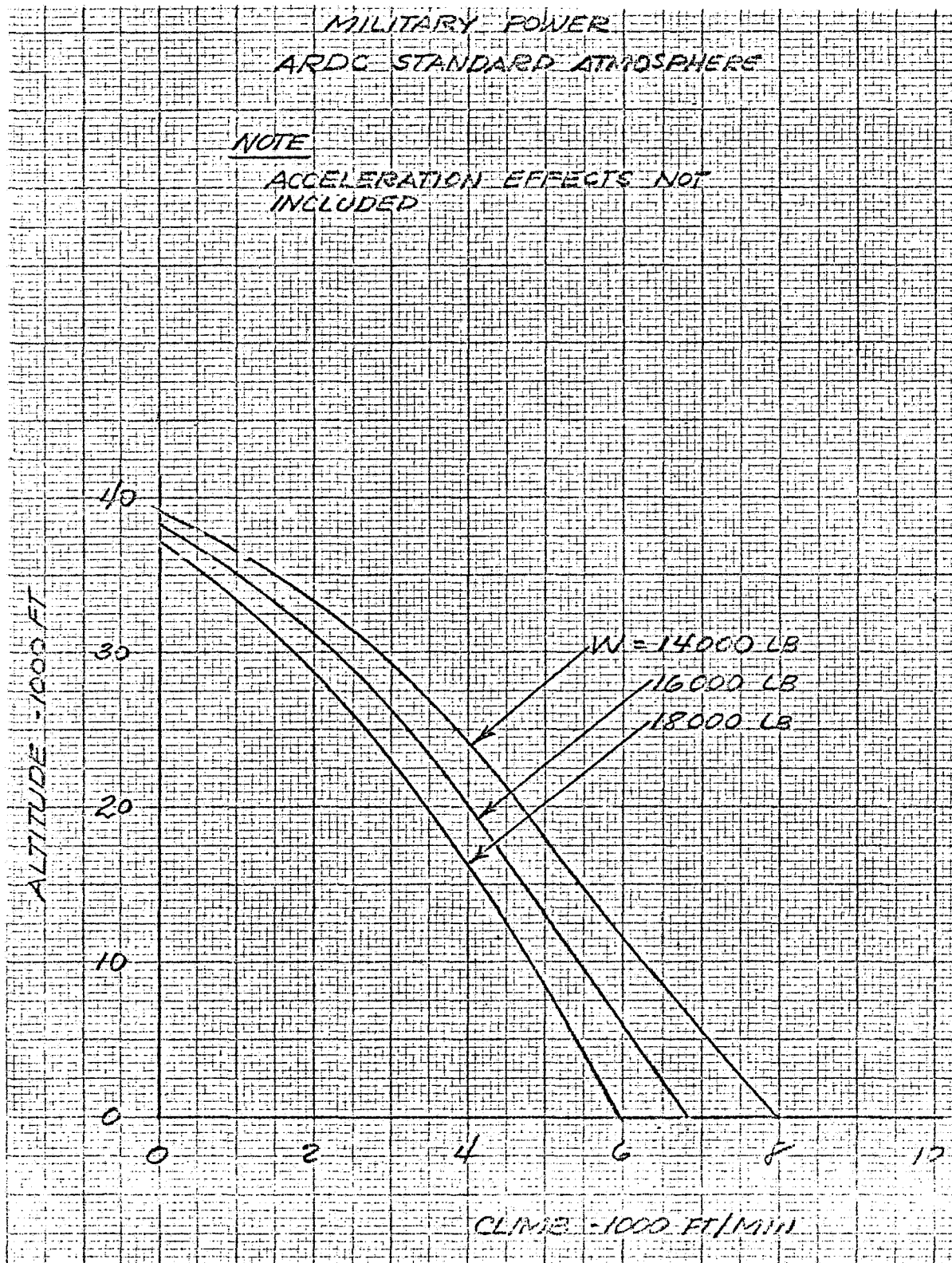


FIGURE 3-7. CLIMB

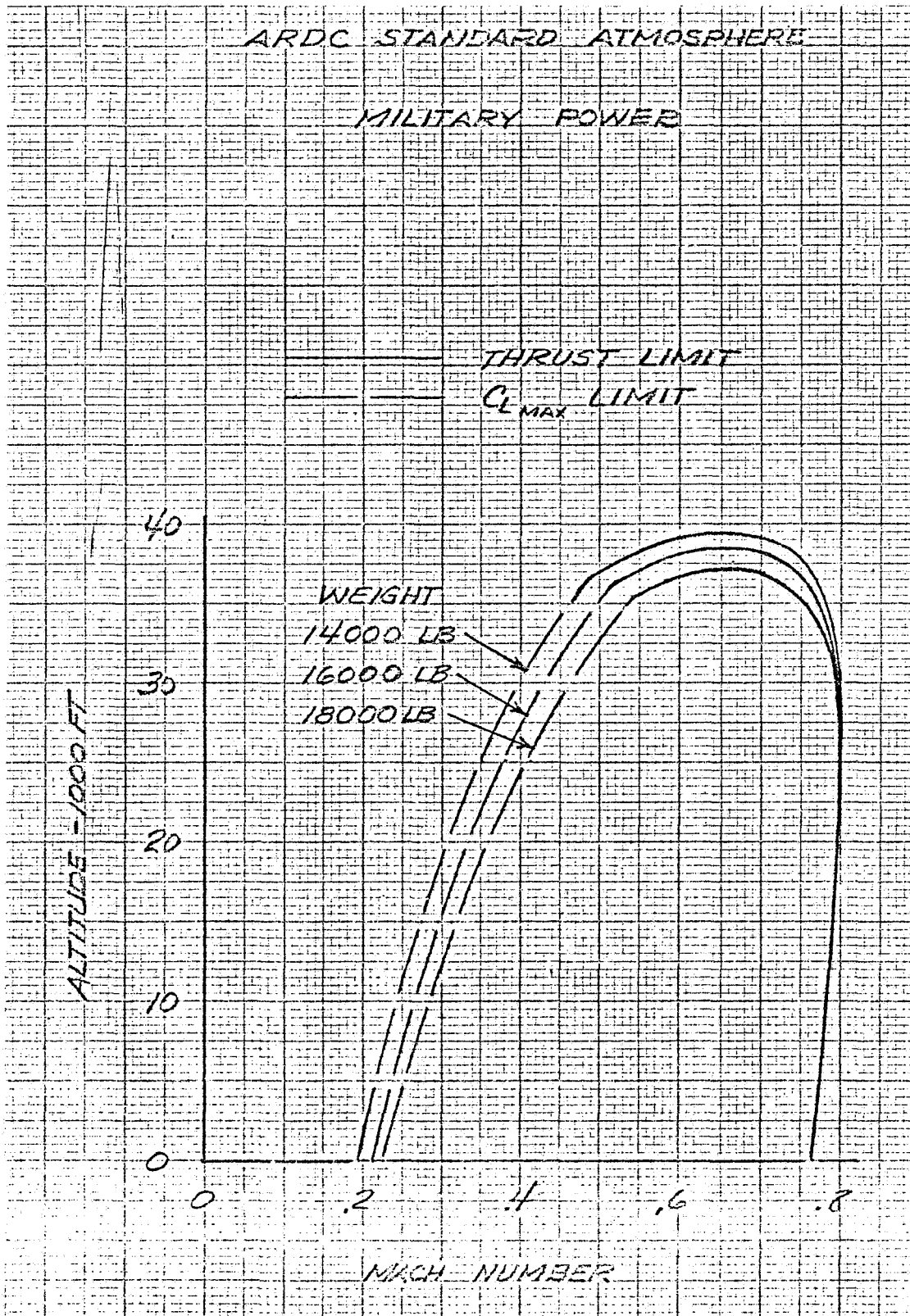


FIGURE 3-8. MACH NUMBER SUMMARY

### 3.1.3 Weights

The gross weights are as follows:

Design gross weight	Direct Lift Mode - <b>16,300</b> lbs. Composite Mode - <b>18,000</b> lbs.
Design ramp weight	Direct Lift Mode - 16,600 lbs. Composite Mode - <b>18,300</b> lbs.
Minimum operating weight	Direct Lift Mode - <b>13,396</b> lbs. Composite Mode - <b>13,193</b> lbs.

The design gross weight is the maximum weight for conventional and V/STOL take-offs and landings.

The design ramp weight includes an additional fuel allowance for engine start and ground checkout and is the maximum ground handling and taxi weight.

The minimum operating weight is the weight with one crew member, oil, unusable fuel, five percent usable fuel, and minimum useful load or ballast necessary to achieve satisfactory balance.

Refer to the Useful Load sheets of **AN-9103-D** Group Weight Statement for the derivation of the loadings.

The weight of the extra lift engines which are required for the direct lift mode are considered a part of the research payload.

### 3.1.4 Center of Gravity Locations

~~The~~ center of gravity travel with normal fuel consumption shall not exceed the limits of ten percent and twenty-three percent of the mean aerodynamic chord. The aircraft loading prior to takeoff shall be that required to maintain the C. G. within these limits under all flight conditions (see Figure **3-9**).

AN-9103-D  
SUPERSEDING  
AN-9103-C

NAME \_\_\_\_\_  
DATE \_\_\_\_\_

PAGE \_\_\_\_\_  
MODEL N-309  
REPORT \_\_\_\_\_

N-309  
AD-4486A  
Composite Mode  
New Airplane

GROUP WEIGHT STATEMENT

ESTIMATED - ~~CALCULATED BY FORM~~  
(Cross out those not applicable)

CONTRACT NO. \_\_\_\_\_  
AIRPLANE, GOVERNMENT NO. \_\_\_\_\_  
AIRPLANE, CONTRACTOR NO. \_\_\_\_\_  
MANUFACTURED BY \_\_\_\_\_

		MAIN	AUXILIARY
ENGINE	MANUFACTURED BY	General Electric	General Electric
	MODEL	J85-19	J85-19
	NO.	2	7*
PROPELLER	MANUFACTURED BY		
	DESIGN NO.		
	NO.		

\*  
Provisions for 8

1 WING GROUP					930
2	CENTER SECTION - BASIC STRUCTURE			158	
3	INTERMEDIATE PANEL - BASIC STRUCTURE				
4	OUTER PANEL - BASIC STRUCTURE (INCL. TIPS 0 LBS.)			548	
5					
6	SECONRARY STRUCTURE (INCL. WINGFOLD MECHANISM 0 LBS.)			82	
7					
8	FLAPS - TRAILING EDGE			51	
9	. LEADING EDGE			61	
10	SLATS				
11	SPOILERS				
12	SPEED BRAKES				
13					
14					
15 TAIL GROUP					309
16	STABILIZER - BASIC STRUCTURE - All Moveable			144	
17	FINS - BASIC STRUCTURE (INCL. DORSAL LBS.)			97	
18	SECONDARY STRUCTURE (STAR. & FINS)				
19	ELEVATOR (INCL. BALANCE WEIGHT LBS.)			33	
20	RUDDERS (IMCL. BALANCE WEIGHT 0 LBS.)				
21	Dorsal Fairing			7	
22	Ventral Fin/Skid			28	
23 BODY GROUP					2,537
24	FUSELAGE OR HULL - BASIC STRUCTURE			1,751	
25	BOOMS - BASIC STRUCTURE				
26	SECOWDARY STRUCTURE - FUSELAGE OR HULL			375	
27	. BOOMS				
28	. SPEEDDRAKES				
29	. DOORS, PANELS & MISC.			411	
30					
31 ALIGHTING GEAR GROUP. LAND (TYPE: Tricycle )					792
32	LOCATION	WHEELS, BRAKES TIRES, TUBES, AIR	STRUCTURE	CONTROLS	
33					
34	Main	170	330	100	600
35	Nose	26	159	7	192
36					
37					
38					
39					
40 ALIGHTING GEAR GROUP - WATER					
41	LOCATION	FLOATS	STRUTS	CONTROLS	
42					
43					
44					
45					
46 SURFACE CONTROLS GROUP					508
47	COCKPIT CONTROLS			68	
48	AUTOMATIC CONTROL Stability Augmentor			118	
49	SYSTEM CONTROLS (INCL. POWER & FEEL CONTROLS All LBS.)			322	
50					
51 ENGINE SECTION OR NACELLE GROUP					680
52	INBOARD				
53	CENTER - Lift Engines			189	
54	OUTBOARD - Lift/Cruise Engines			146	
55	DOORS, PANELS & MISC. (Incl. in nacelles)				
56	Nacelles (Incl. 13 lbs. Access Doors)			345	
57 TOTAL (TO BE BROUGHT FORWARD)					5,756

NAME \_\_\_\_\_

DATE \_\_\_\_\_

# GROUP WEIGHT STATEMENT

## WEIGHT EMPTY

N-309

1	PROPULSION GROUP			4,740
2		AUXILIARY - Lift	RAM - Cruise	
3	ENGINE INSTALLATION	2,709	784	
4	AFTERBURNERS (IF FURN. SEPARATELY)			
5	ACCESSORY GEAR BOXES & DRIVES - CSD		140	
6	SUPERCHARGERS (FOR TURBO TYPES)			
7	AIR INDUCTION SYSTEM	35	36	
8	EXHAUST SYSTEM	14	138	
9	<del>XXXXXXXXXXXX</del> Swivel Nozzle/Diversers	231	150	
10	LUBRICATING SYSTEM	7	2	
11	TANKS (Incl. in Eng. Wt.)			
12	COOLING INSTALLATION			
13	DUCTS, PLUMBING, ETC.	7	2	
14	FUEL SYSTEM		<del>XXXXXX</del> 375	
15	TANKS - PROTECTED			
16	- UNPROTECTED		90	
17	PLUMBING, ETC.		285	
18	WATER INJECTION SYSTEM			
19	ENGINE CONTROLS	50	28	
20	STARTING SYSTEM	26	15	
21	PROPELLER INSTALLATION			
22				
24	AUXILIARY POWER PLANT GROUP			
25	INSTRUMENTS & NAVIGATIONAL EQUIPMENT GROUP			171
26	HYDRAULIC & PNEUMATIC GROUP			190
27	Hover Control System (Ducting & Valves)			528
28				
29	ELECTRICAL GROUP			335
30				
31				
32	ELECTRONICS GROUP			220
33	EQUIPMENT		174	
34				
35				
36	ARMAMENT GROUP (INCL. GUNFIRE PROTECTION LBS.)			
37	FURNISHINGS & EQUIPMENT GROUP			410
38	ACCOMMODATIONS FOR PERSONNEL		305	
39	MISCELLANEOUS EQUIPMENT		44	
40	FURNISHINGS		26	
41	EMERGENCY EQUIPMENT		35	
42				
43	AIR CONDITIONING & ANTI-ICING EQUIPMENT GROUP			68
44	AIR CONDITIONING & Equipment Cooling		61	
45	ANTI-ICING - Cabin Defog		7	
46				
47	PHOTOGRAPHIC GROUP			
48	AUXILIARY GEAR GROUP			
49	HANDLING GEAR			
50	ARRESTING GEAR			
51	CATAPULTING GEAR			
52	ATO GEAR			
53				
54				
55	<del>XXXXXXXXXXXX</del> Contingency			267
56	TOTAL FROM PG. 2			5,756
57	WEIGHT EMPTY			12,685

NAME \_\_\_\_\_

DATE \_\_\_\_\_

# GROUP WEIGHT STATEMENT USEFUL LOAD & GROSS WEIGHT

PAGE \_\_\_\_\_

MODEL N-309

REPORT \_\_\_\_\_

1	LOAD CONDITION			Composite Mode		Direct Lift Mode	
				VTOL	Operating Wt. Empty	VTOL	Operating Wt. Empty
2				400	400	400	400
3	CREW (NO. 2 )						
4	PASSENGERS (NO. )						
5	FUEL	Type	Gals.				
6	UNUSABLE	JP-4	6.9	45	45	45	45
7	INTERNAL-Flight	JP-4	616.5	4,007			
8	-Flight	JP-4	369.8			2,404	
9							
10	EXTERNAL						
11							
12	BOMB BAY						
13							
14	OIL (9 pounds per engine)			63	63	70	70
15	TRAPPED						
16	ENGINE						
17							
18	FUEL TANKS (LOCATION )						
19	WATER INJECTION FLUID ( GALS)						
20							
21	BAGGAGE						
22	CARGO						
23							
24	ARMAMENT						
25	GUNS (Location)	Fix. or Flex.	Qty.	Cal.			
26							
27							
28							
29							
30							
31							
32	AMMUNITION						
33							
34							
35							
36							
37							
38							
39	INSTALLATIONS (BOMB, TORPEDO, ROCKET, ETC.)						
*40	BOMB OR TORPEDO RACKS						
41							
42	Variable Stability System			500		500	
43	NASA Research Equipment			300		---	
44							
45							
46	EQUIPMENT						
47	PYROTECHNICS						
48	PHOTOGRAPHIC						
49							
*50	OXYGEN						
51							
52	MISCELLANEOUS						
53							
54							
55	USEFUL LOAD			5,315	508	3,419	515
56	WEIGHT EMPTY			12,685	12,685	12,881	12,881
57	GROSS WEIGHT			18,000	13,193	16,300	13,396

\*All items quantified as multiple empty.

NAME \_\_\_\_\_  
DATE \_\_\_\_\_GROSS WEIGHT STATEMENT  
DIMENSIONAL & STRUCTURAL DATAMODEL \_\_\_\_\_  
REPORT \_\_\_\_\_

1 LENGTH - OVERALL (FT.) 55.58				HEIGHT - OVERALL - STATIC (FT.) 15.33			
2	Main Floats	Aux. Floats	Booms	Fuse or Hull	Inboard	Nacelles - Center	Outboard
3 LENGTH - MAX. (FT.)				46.25	121		
4 DEPTH - MAX. (FT.)				5.250	40		
5 WIDTH - MAX. (FT.)				5.667	28		
6 WETTED AREA (SQ. FT.)				723	150		
*7 FLOAT OR HULL DISPL. - MAX (LBS.)							
8 FUSELAGE VOLUME (CU. FT.)	PRESSURIZED				TOTAL		
9					Wing	H. Tail	V. Tail
10 GROSS AREA (SQ. FT.)					210	66.6	48.0
11 WEIGHT/GROSS AREA (LBS./SQ. FT.)					4.42	1.95	3.0
12 SPAN (FT.)					35.5	15.7	7.6
13 FOLDED SPAN (FT.)							
14							
15 SWEEPBACK - AT 25% CHORD LINE (DEGREES)					20°	27°	40°
16 - AT % CHORD LINE (DEGREES)							
**17 THEORETICAL ROOT CHORD - LENGTH (INCHES)					101.5	78.5	117.0
18 - MAX. THICKNESS (INCHES)					13.195	7.85	11.70
**19 CHORD AT PLANFORM BREAK - LENGTH (INCHES)							
20 - MAX. THICKNESS (INCHES)							
***21 THEORETICAL TIP CHORD - LENGTH (INCHES)					40.6	24.0	35.0
22 - MAX. THICKNESS (INCHES)					4.872	2.40	3.50
23 DORSAL AREA, INCLUDED IN <del>XXXXXXXXXX</del> (V. TAIL) AREA (SQ. FT.)							3.5
24 TAIL LENGTH - 25% MAC WING TO 25% MAC H. TAIL (FT.)							15.0
25 AREAS (SQ. FT.)	Flaps	L.E.	23.2	T.E.	23.2		
26	Lateral Controls	Slats		Spoilers		AILERONS	8.8 (aft of hinge line)
27	Speed Brakes	Wing		Fuse. or Hull			
28							
29							
30 ALIGHTING GEAR	(LOCATION)			Nose	Main		
31 LENGTH - OLEO EXTENDED - $\phi$ AXLE TO $\phi$ TRUNNION (INCHES)				62.5	60.0		
32 OLEO TRAVEL - FULL EXTENDED TO FULL COLLAPSED (INCHES)				20.0	19.25		
33 FLOAT OR SKI STRUT LENGTH (INCHES)							
34 ARRESTING HOOK LENGTH - $\phi$ HOOK TRUNNION TO HOOK POINT (INCHES)							
35 HYDRAULIC SYSTEM CAPACITY (GALS.)							
36 FUEL & LUBE SYSTEMS	Location	No. Tanks	****Gals. Protected	No. Tanks	****Gals. Unprotected		
37 Fuel - Internal	Wing						
38	Fuse. or Hull			6	707.7		
39 - External							
40 - Bomb Bay							
41							
42							
43							
44							
45 STRUCTURAL DATA - CONDITION		Fuel in Wings (Lbs.)	Stress Gross Weight	Ult. L.F.			
46 FLIGHT		0	18,000	5.625			
47 LANDING							
48							
49 MAX. GROSS WEIGHT WITH ZERO WING FUEL							
50 CATAPULTING							
51 MIN. FLYING WEIGHT							
52 LIMIT AIRPLANE LANDING SINKING SPEED (FT./SEC.)							
53 WING LIFT ASSUMED FOR LANDING DESIGN CONDITION (%W)							
54 STALL SPEED - LANDING CONFIGURATION - POWER OFF (KNOTS)							
55 PRESSURIZED CABIN - ULT. DESIGN PRESSURE DIFFERENTIAL - FLIGHT (P.S.I.)							
56							
57 AIRFRAME WEIGHT (AS DEFINED IN AN-W-11) (LBS.)		7,837 lbs.					

\*Lbs. of sea water @ 64 lbs./cu. ft.  
\*\*Parallel to  $\phi$  at  $\phi$  airplane.

\*\*\*Parallel to  $\phi$  airplane.  
\*\*\*\*Total usable capacity.

NOTES

1. GEAR DOWN CONDITION SHOWN. EFFECT OF GEAR RETRACTION IS NEGLIGIBLE.
2. TWO MAN CREW CONDITION SHOWN. EFFECT OF AFT MAN OUT IS APPROXIMATELY  $+1.8\%$  ( $+1.8$  IN.) AT 18,000 LBS. AND  $+2.4\%$  ( $+1.8$  IN.) AT 14,000 LBS.

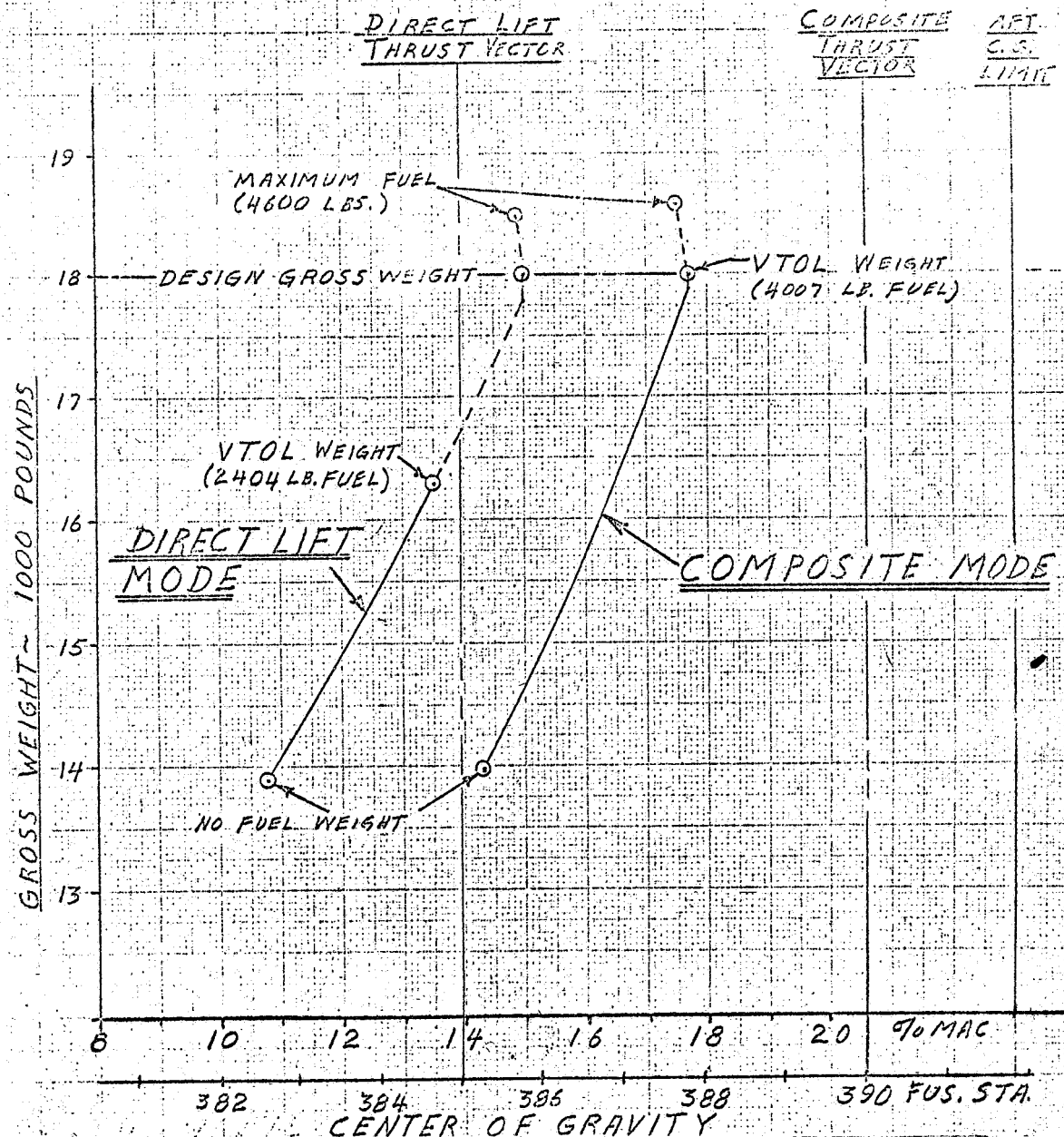


FIGURE 3-9. CENTER OF GRAVITY DIAGRAM

GENERAL DATA**3.1.5 Areas**

Wing Area Total (Theoretical) Including Aileron and Flap	<b>210.0 Sq. Ft.</b>
Wing Trailing Edge Flap Area	<b>23.2 Sq. Ft.</b>
Wing Leading Edge Flap Area	<b>23.2 Sq. Ft.</b>
Aileron Area Aft of Hinge Line	<b>8.8 Sq. Ft.</b>
Horizontal Tail Area Total	<b>66.6 Sq. Ft.</b>
Exposed	<b>45.0 Sq. Ft.</b>
Vertical Tail Area Total (Theoretical, not including Dorsal)	<b>48.0 Sq. Ft.</b>
Rudder Area Aft of Hinge Line	<b>10.6 Sq. Ft.</b>

**3.1.6 Dimensions and General Data**

Wing	
Span (Maximum)	<b>36.8 Ft.</b>
Theoretical	<b>35.5 Ft.</b>
Chord	
At Root	<b>101.5 In.</b>
At Construction Tip	<b>40.6 In.</b>
Mean Aerodynamic	<b>75.3 In.</b>
Airfoil Section	
At Root	NACA 64A013
At Tip	NACA 64A012
Incidence	0°
Sweepback at 25 percent Chord	20°
Dihedral	0°
Aspect Ratio	6
Taper Ratio	.40

Ailerons		
Span	4.25 Ft.	
Chord/Wing Chord	25%	
Flap Trailing Edge		
Span	8 Ft.	
Chord/Wing Chord	25%	
Flap Leading Edge		
Span	11.3 Ft.	
Chord/Wing Chord	20%	
Horizontal Tail		
Span	15.7 Ft.	
Chord		
Root	78.5 In.	
Tip	24 In.	
Mean Aerodynamic	48 In.	
Airfoil Section	NACA 64A010	
Sweepback at 25 percent Chord	27°	
Dihedral	-10°30'	
Aspect Ratio	3.7	
Taper Ratio	.30	
Vertical Tail		
Span	7.6 Ft.	
Chord		
Root	117 In.	
Tip	35 In.	
Mean Aerodynamic	83 In.	
Airfoil Section	NACA 64A010	
Sweepback at 25 percent Chord	40°	
Aspect Ratio	1.2	
Taper Ratio	.30	

**3 1.7 General**

Height Above Ground Over Highest Fixed Part of Aircraft All Wheels in Contact	15 Ft. 4 In.
Length, Maximum	55 Ft. 7 In.
Distance From Wing MAC Quarter Chord Point to Horizontal Tail MAC Quarter Chord Point	180 In.
Distance From Wing MAC Quarter Chord Point to Vertical Tail MAC Quarter Chord Point	189 In.
Angle Between Reference Line and Wing Zero Lift Line (All Surfaces Neutral)	0°
Ground Angle, All Wheels Contact, Static	1°30'
Max. Tail Down Static	12°
Wheel Size (Rim Diameter)	
Main Wheel	11 In.
Nose Wheel	8 In.
Tire Size	
Main Wheel	22 x 8.5 - 11 Type VIII 14 Ply Rating
Nose Wheel	18 x 5.5 Type VII 8 Ply Rating
Tread of Main Wheels	194 In.
Wheel Base	206 In.
Vertical Travel of Axle From Extended to Fully Compressed Position	
Main Landing Gear	19.25 In.
Nose Landing Gear	20 In.

**3.1.8 Control Movements and Corresponding Control Surface Movements**

Nominal control surface and control movement on each side of neutral position for full movements as limited by stops shall be as follows:

Rudder	± 25°
Rudder Pedals	± 3.5 inches forward and aft
Horizontal Stabilizer	25° up 15° down (L. E. )
Horizontal Stabilizer Control	6 In. aft 4 In. forward
Ailerons	20° up 20° down
Aileron Control	4.25 In. right or left
Wing Flap	
Trailing Edge	40° Total
Leading Edge	25° Total

**3.1.8.1 CONTROL SURFACE RATES.** The maximum no-load surface travel rates as limited by actuator capability, shall be not less than:

Horizontal tail	40 <sup>0</sup> /sec.
Rudder	50 <sup>0</sup> /sec.
Aileron	40 <sup>0</sup> /sec.

### **3.2 GENERAL FEATURES OF DESIGN AND CONSTRUCTION**

#### **3.2.1 General Internal Arrangement**

The general internal arrangement of this aircraft shall be as shown on the inboard profile drawing AD-4513 , Figure 3-10.

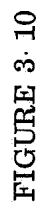
The fuselage shall consist of three major assemblies: the forward fuselage, center body, and aft fuselage. The forward fuselage features a tandem cockpit with ejection seats and side opening canopy, equipment and fuel bay, a reaction control nozzle and nose landing gear. The center fuselage is essentially the propulsion area. This section consists of the seven lift engines mounted in the body and two lift/cruise engines mounted in nacelles. The wing attaches to the body in this section and features a continuous wing structural box through the fuselage. The wing mounts a wide tread main landing gear. The aft fuselage contains the aft fuel and equipment bay, the aft reaction control nozzle and mounts the vertical and horizontal tail, A tail bumper is also provided in this area to protect the aft nozzle from damage at extreme landing conditions. Sufficient space is allocated for routing of systems through the body and wings as required, in an efficient manner.

#### **3.2.2 Selection of Materials**

Specifications and standards for all materials, parts, and processes which are not specifically designated herein shall be selected in accordance with applicable military or contractor specifications.

#### **3.2.3 Workmanship**

Workmanship shall conform to high grade aircraft practices and shall be commensurate with the requirements of publications listed in Paragraph 2.3 of this specification.



#### 3.2.4 Production, Maintenance, and Repair

Consideration shall be given in the design of the aircraft to ease of production, rapid installation of power plant and equipment, and ease of general maintenance. Special attention shall be given component parts of the structure and installations toward their ready access for inspection, maintenance, and repair. To the extent practicable in this experimental aircraft, the fuselage and wings shall be designed to facilitate the removal and replacement of damaged sections. The members that are most liable to damage shall be designed in a manner to minimize long, laborious repair and replacement processes. Requirements for special tools shall be kept to a minimum.

#### 3.2.5 Interchangeability and Replaceability

The component parts and/or assemblies of the airplane described herein shall be interchangeable or replaceable in accordance with Appendix IV of this specification.

#### 3.2.6 Finish

The finish of the aircraft and parts shall be in accordance with Northrop Corporation, Norair Division Finish Specifications. Special attention shall be given in areas of dissimilar metals and corrosion areas. The airplane's exterior surfaces shall be aerodynamically smooth and include insignia and appropriate markings.

#### 3.2.7 Identification and Marking

The aircraft and its components shall be identified and otherwise marked to conform to requirements of Northrop Corporation, Norair Division process specification. All vents, drains and access plates not identified shall be for maintenance purposes.

#### 3.2.8 Extreme Temperature Operation

The airplane as a whole and its on-board equipment shall be so constructed that it will function satisfactorily at any or all temperatures to be encountered between ground level and its service ceiling. As a minimum, the operable range shall be from -40°F to +135°F.

### 3.2.9 Climatic Requirements

The aircraft and its equipment shall not be adversely affected by other climatic conditions anticipated during its intended mission ~~or~~ during ferry flights.

### 3.2.10 Lubrication

Lubrication requirements and provisions for this aircraft shall generally conform to Specification **MIL-L-6680**.

### 3.2.11 Equipment and Furnishing Installation

Equipment and furnishings specified in Appendices **1-A** and **1-B** of this specification and described in other portions of this specification, shall be installed in the quantity and under the applicable conditions set forth.

### 3.2.12 Crew

The crew shall consist of an evaluation pilot, (front seat) and a safety pilot, (~~aft~~ seat) of the tandem cockpit arrangement. The aircraft shall have dual controls and displays, and be in accordance with HIAD where applicable. See Northrop drawings AD ~~4433B~~ and AD ~~4434B~~ (Figures **3-11** and **3-12**).

### 3.2.13 Noise and Vibration Requirements

The aircraft and its equipment shall function normally in all extremes of noise and vibration that will be encountered in its own environment. The design of the ~~air-~~plane shall be such that the probability of disastrous fatigue failure resulting from vibrations (including those produced by noise ~~or~~ other oscillatory ~~air~~ flows) during the service life of the airplane will be essentially nil, In those types of structure where redundancy, slow rate of crack growth, and inspection enable repair in time to avoid disastrous fatigue failure or reduction in strength, the design of the airplane shall be such that the repair (i.e. , total man-hours of repair time divided by, the life of the airplane in flight hours) in normal service operation is compatible with research concept ~~of~~ this aircraft.

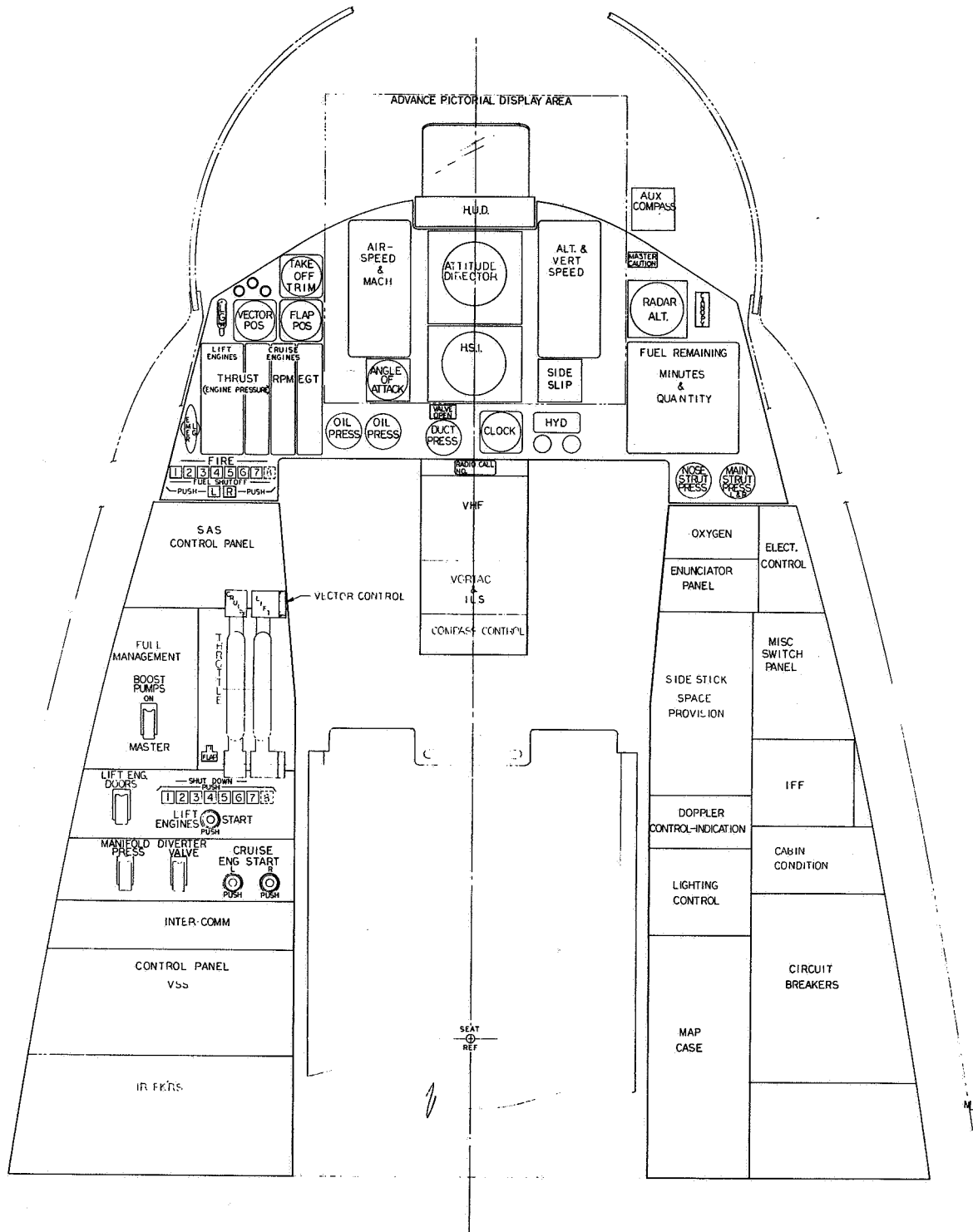


FIGURE 3-11

ADVANCED SYSTEMS DESIGN			
DESIGN APPROVED AND AUTHORIZED FOR RELEASE BY:	DATE: 1/2	BY: [Signature]	1/2
NORTHROP CORPORATION		N-309	1/2
A DIVISION OF NORTHROP CORPORATION		AD-4433	1/2
COCKPIT ARRANGEMENT - YF-12		AD-4433	1/2
TANDEM (FRONT)		AD-4433	1/2

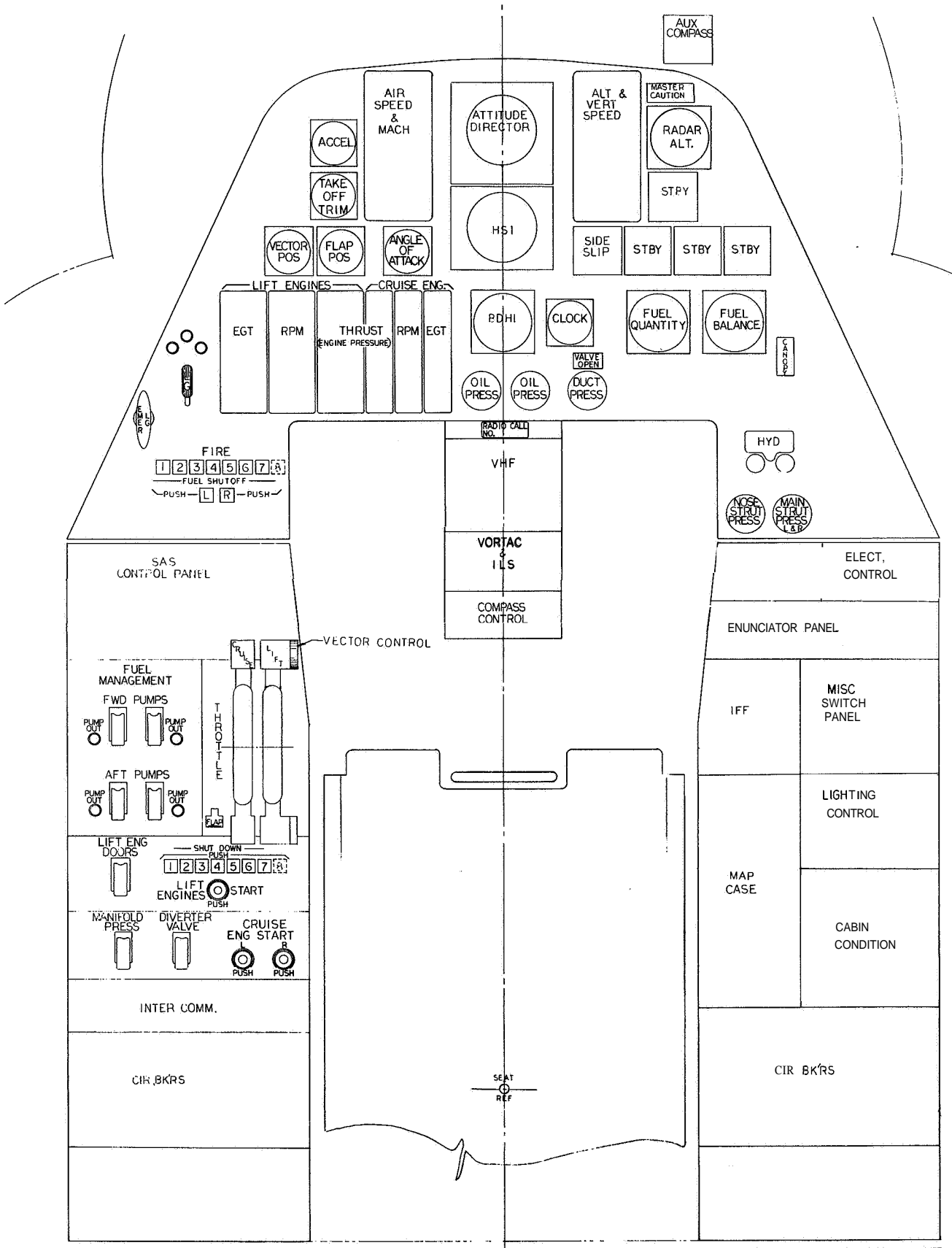


FIGURE 3-12

ADVANCED SYSTEMS DESIGN			
DESIGN AUTHORITY AND APPROVING AUTHORITY:	DATE: 1/2	REVISED:	
NORTHROP CORP.	11-308	DESIGNED BY: P. J. H. V. J.	
COCKPIT ARRANGEMENT - Y/SOL			
TANDEM (REAR)			

### 3.3. AERODYNAMICS

#### 3.3.1 General

The aircraft shall, where applicable, meet the specifications of NASA, NAS1-6777 and RFP L-7151; MIL-F-8785 (ASG), Amendment 4, and AGARD 408. No deviations from these specifications are anticipated.

#### 3.3.2 Stability and Control

**3.3.2.1 CONVENTIONAL FLIGHT REGIME.** The aircraft shall, where applicable, comply with the requirements of MIL-F-8785(ASG), Amendment 4 (Class III aircraft, up to 25,000 feet, 450 knots speed or 0.8 limit Mach number). Weapons delivery requirements and the like shall not be considered.

**3.3.2.1.1 Static Stability.** Positive static longitudinal stability is illustrated in Figure 3-13, which shows the variation of stick-fixed neutral point and maneuver point with Mach number for the rigid airframe.

Maneuvering stability is indicated in Figure 3-14 showing variation of tail angle per g with Mach number.

Positive directional and lateral static stability exists at all attainable lift coefficients.

**3.3.2.1.2 Dynamic Stability.** Longitudinal: short period mode characteristics are shown in Figure 3-15 for two extreme flight conditions, namely  $V = 180$  knots at S. L. and  $M = .75$  at 25,000 feet. In both cases,  $W = 18,000$  pounds (maximum VTO weight) with the c. g. aft. With no stability augmentation it is seen that the aircraft closely approaches the requirements of MIL-F-8785 (ASG), Amendment 4.

At both flight conditions the Phugoid mode exhibits positive damping with a period in excess of 15 seconds.

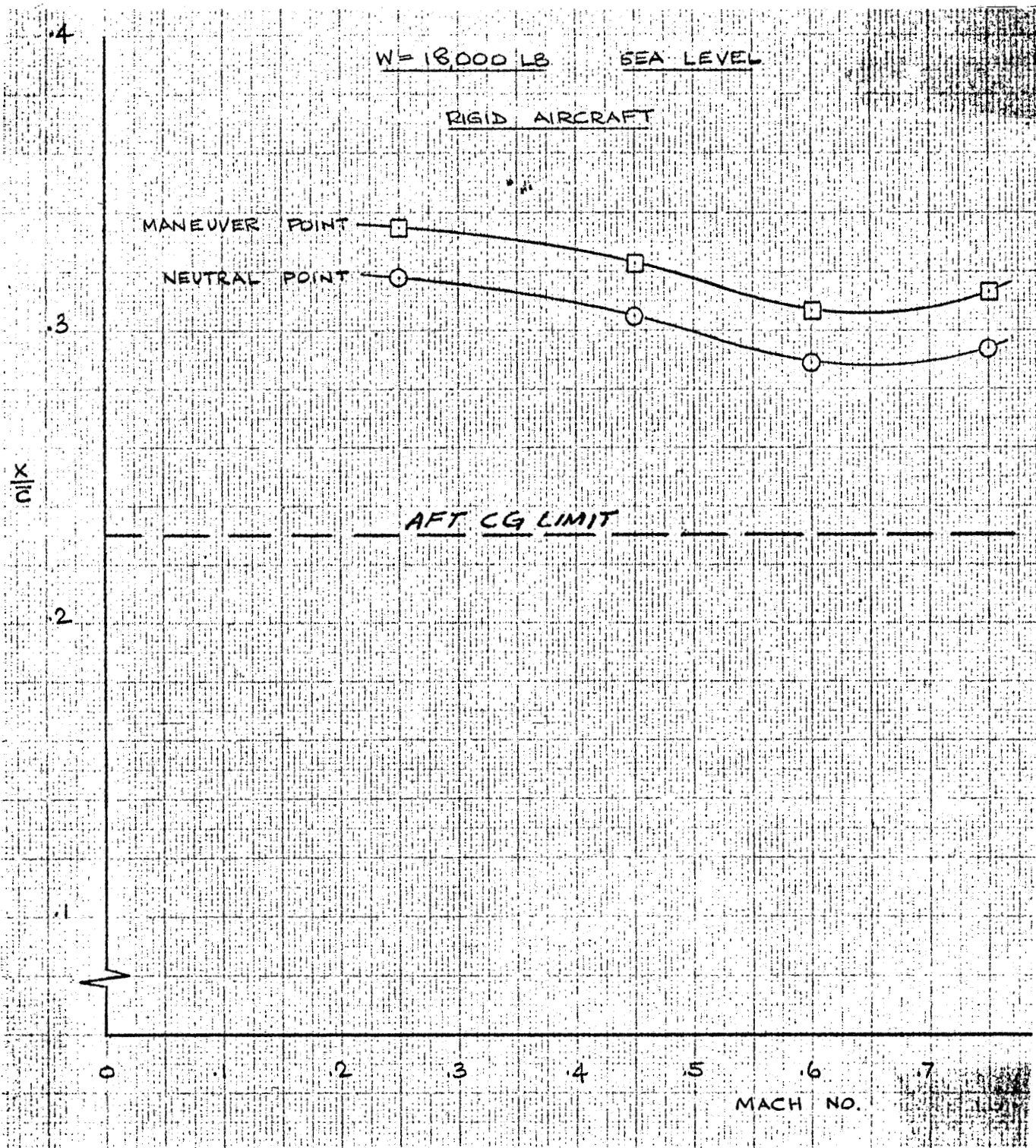


FIGURE 3-13. STABILITY AND CONTROL - STICK-FIXED NEUTRAL POINT AND MANEUVER POINT

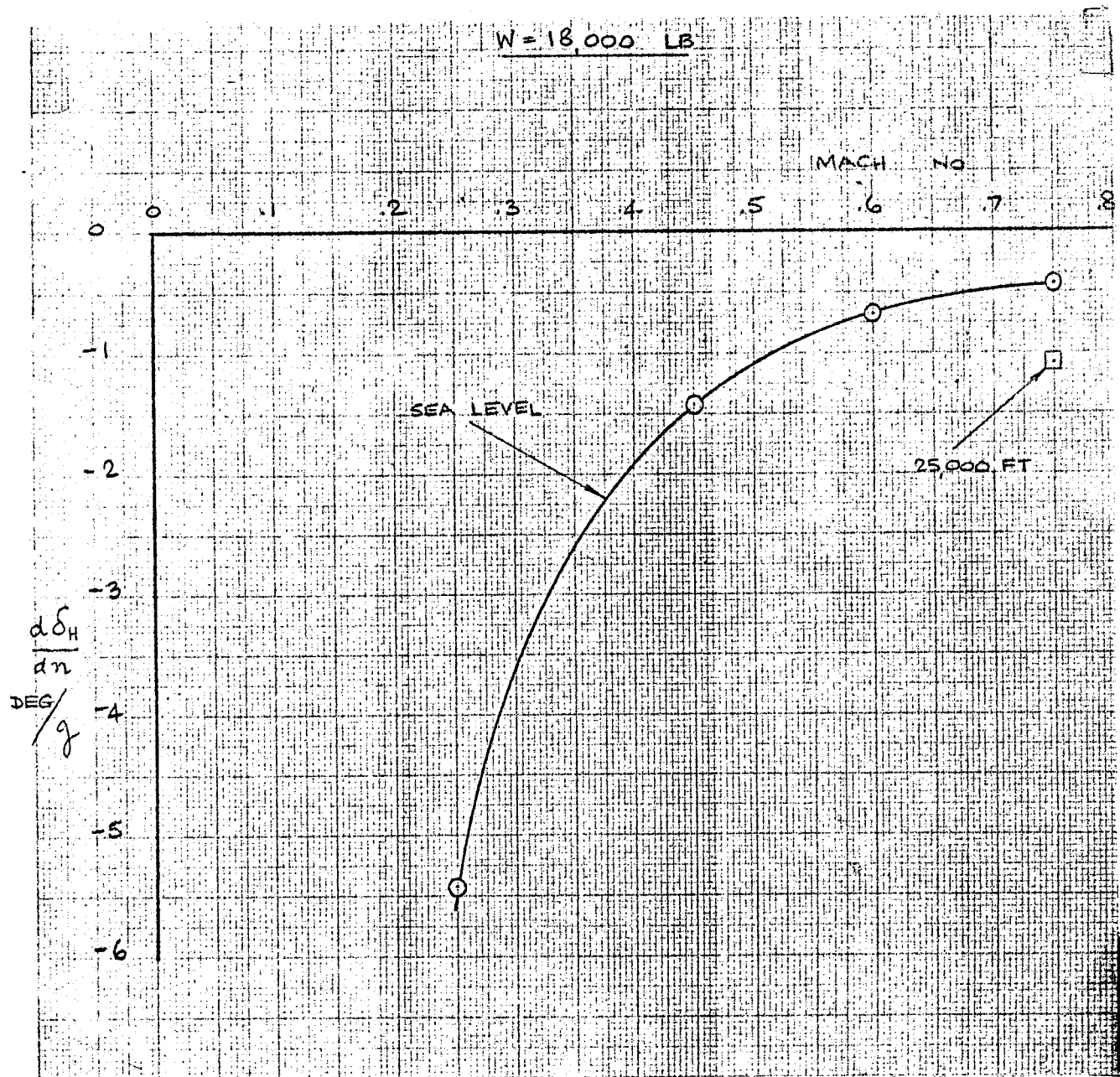


FIGURE 3-14. STABILITY AND CONTROL - TAIL, ANGLE PER G

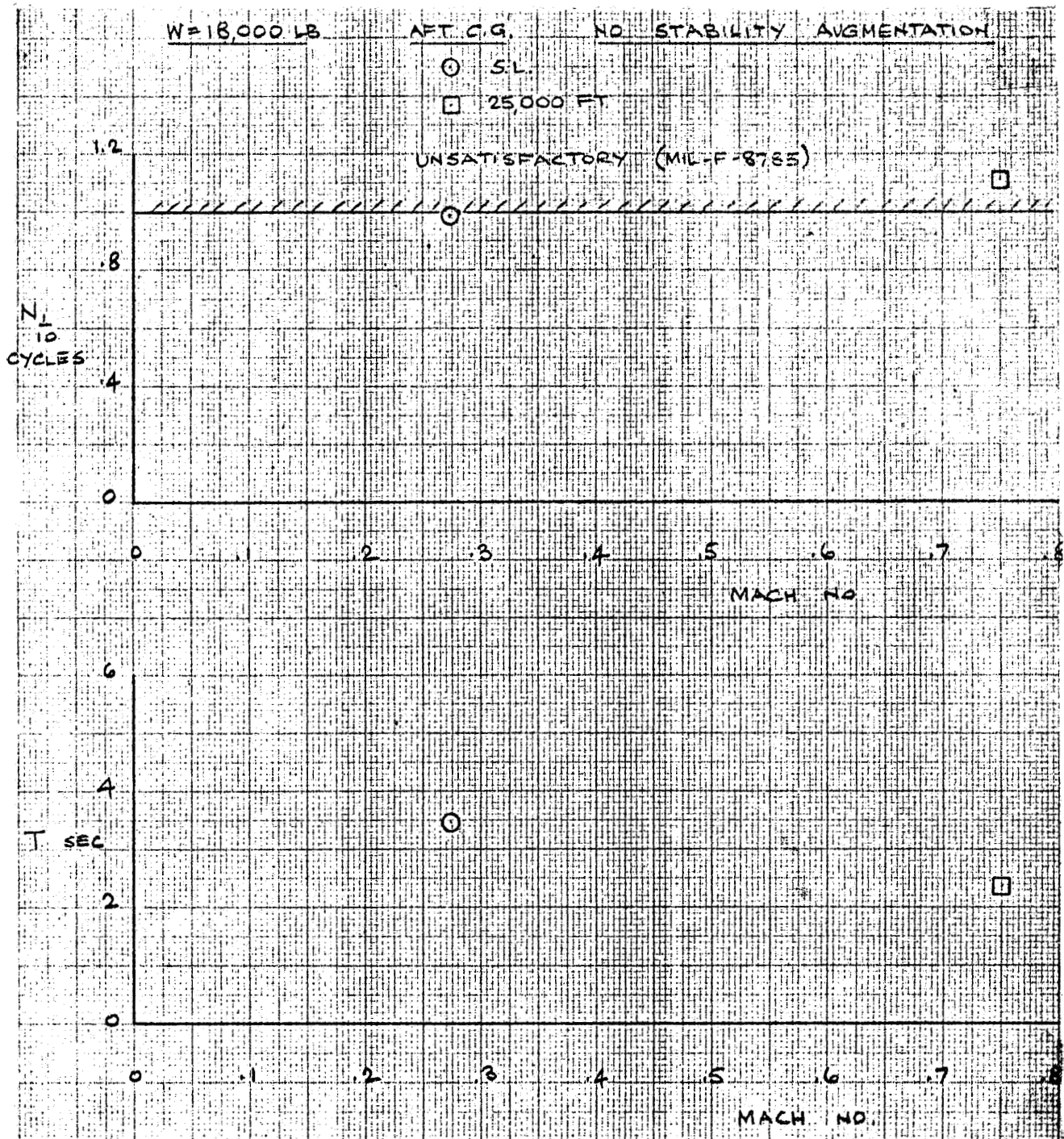


FIGURE 3-15. STABILITY AND CONTROL - LONGITUDINAL SHORT PERIOD CHARACTERISTICS IN CONVENTIONAL FLIGHT - N-309

Lateral-directional: Dutch roll characteristics are shown in Figure 3-16 for the same flight conditions as above. With no stability augmentation the aircraft meets the "augmenters on" requirements of MIL-F-8785 (ASG).

Spiral mode characteristics meet the MIL-F-8785 (ASG) requirement ( $t_2 \nless 20$  sec.). At 180 knots at sea level, the spiral mode doubles amplitude in 65 seconds, while at .75 Mach number at 25,000 feet, the spiral mode is convergent.

3.3.2.1.3 Roll Performance. The aircraft shall meet the requirements of MIL-F-8785 (ASG). Roll performance is shown in Table 1 for a step input of full aileron control. Specification requirements are shown in parentheses.

TABLE 1. STABILITY AND CONTROL - ROLL PERFORMANCE

$$\delta_a = 20^\circ \quad W = 18,000 \text{ pounds}$$

h ft. M V knots eas	S. L. 0.25 165	S. L. 0.68 450	25,000 0.75 302
$\frac{pb}{2v}$	0.1223 (0.07)	0.1223 (0.07)	0.1223
$p_{ss}$ deg/sec	109.5	300	301
$\tau_R$ sec	0.570	0.208	0.463
$\phi$ deg $t = 1$ sec.	58.2	237	177 (90)

NOTES: (1) MIL-F-8785 (ASG) Amendment 4 requirements are shown in parenthesis.

(2) At M = 0.25, average  $\left(\frac{pb}{2v}\right)$  for first  $30^\circ$  of bank = 0.05 (0.05)

### 3.3.2.2 HOVERING FLIGHT REGIME

3.3.2.2.1 Stability. Stick fixed stability shall be equivalent to or superior than that recommended in AGARD 408. Stability augmentation shall be provided about **all** axes to achieve this objective.

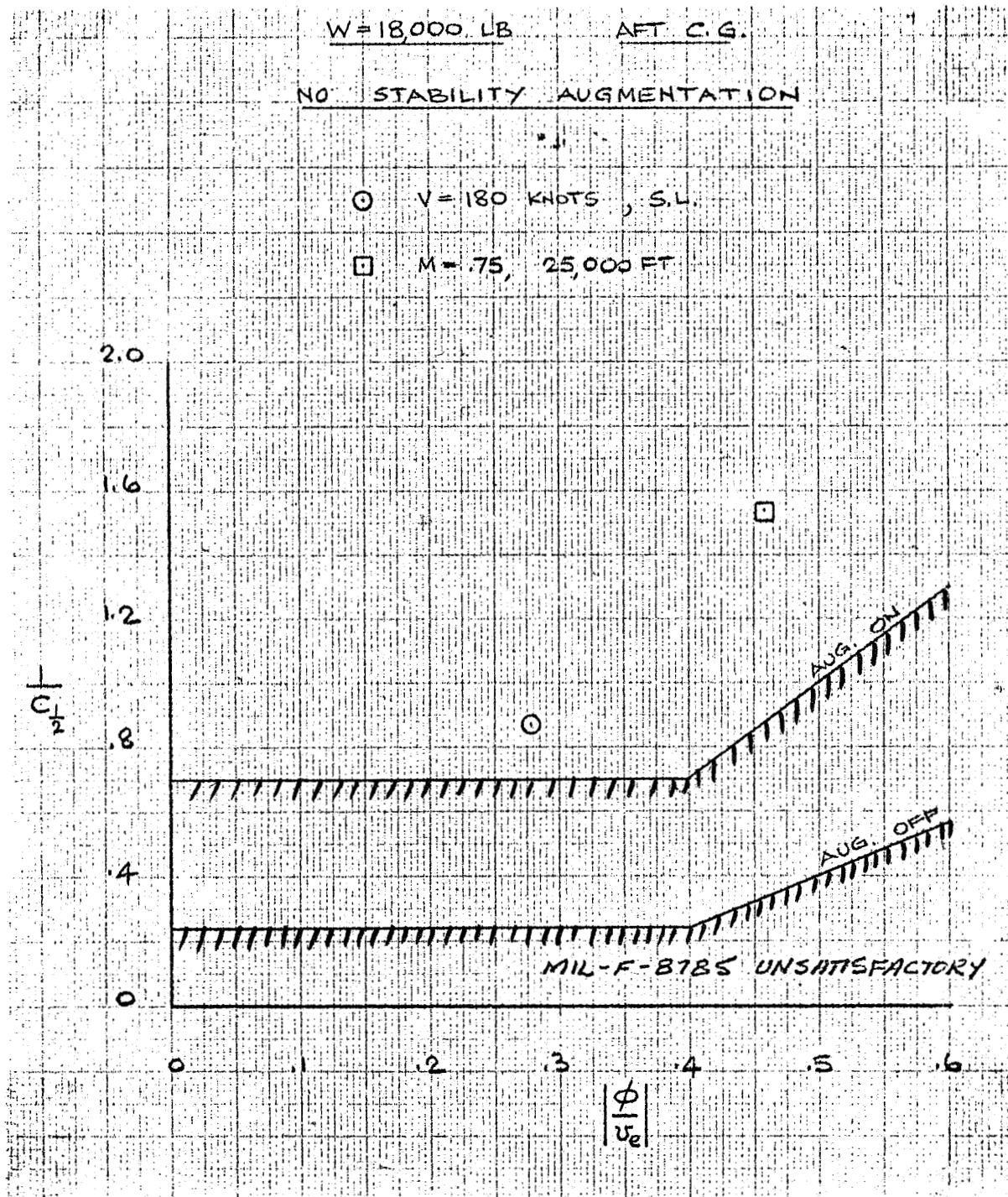


FIGURE 3-16. STABILITY AND CONTROL - DUTCH ROLL CHARACTERISTICS IN CONVENTIONAL FLIGHT - N-309

**3.3.2.2.2 Control Requirements.** Control power provided is in accordance with levels denoted in succeeding paragraphs. The reaction control system utilizes compressor bleed **air** ducted to the aircraft extremities. It supplants aerodynamic control at the low airspeeds where conventional controls become ineffective.

**3.3.2.2.2.1 Single Axis Control Thrust.** Minimum single axis control thrust shall be the equivalent of at least:

Pitch: **1.5** times that recommended in **AGARD 408**.

Roll: **2.0** times that recommended in **AGARD 408**.

Yaw: **1.5** times that recommended in **AGARD 408**.

The "nominal" control requirements are thus,

Axis	Pitch	Roll	Yaw
Response for full control input (deg. in first sec.)	$\frac{450}{(W \pm 1000)^{1/3}}$	$\frac{600}{(W \pm 1000)^{1/3}}$	$\frac{270}{(W \pm 1000)^{1/3}}$
Damping (ft. -lb./rad./sec.)	$15(I_v)^{0.7}$	$25(I_x)^{0.7}$	$27(I_z)^{0.7}$

**3.3.2.2.2.2 Simultaneous Control Thrust.** Simultaneous rather than 100 percent single axis control thrust requirements make the greatest demands on available engine bleed air. With all engines operating (normal) the requirements shall be 60 percent of maximum control simultaneously on all axes, and **20** percent pitch and yaw control, plus **50** percent roll control with one engine out (emergency).

Comparisons between simultaneous control thrusts required and available, expressed as a function of engine thrust ratio are shown in Figure **3-17**. Data for both normal and emergency operation are included. The lowest weight condition shown is with approximately 15 percent fuel.

Requirements are exceeded at maximum and minimum weight under both normal and emergency conditions.

**3.3.2.2.2.3 Engine Out (Emergency) Control Power.** In addition, the following control margins shall be available after trimming out the failure of the most critical engine ~~at~~ both the VTO weight and the empty weight :

Pitch: 20 percent of the "nominal" hover value.

Roll: 50 percent of the "**nominal**" hover value.

Yaw: **20** percent of the "**nominal**" hover value,

where the "**nominal**" hover control powers are those discussed in **3.3.2.2.2.1** above.

At both weights the control required to meet these requirements is less than the "nominal" values and is thus not critical.

**3.3.2.2.2.4 Steady Winds.** The control margins specified in **3.3.2.2.2.3** above shall be available after trimming out a **35** knot wind from any direction.

At both maximum VTO weight and empty weight the control required to meet these requirements is less than the "**nominal**" values and is thus not critical.

### **3.3.2.3 TRANSITION FLIGHT REGIME.**

**3.3.2.3.1 Stability.** Stick fixed stability shall be equivalent to **or** superior than that recommended in AGARD **408**. Stability augmentation about all axes will be utilized to achieve this objective.

**3.3.2.3.2 Control Moment Required.** Total control moment is a mixture of reaction control and, where effective, conventional aerodynamic control. Aircraft response through transition shall satisfy the requirements presented in the table of **3.3.2.2.2.1** above.

**3.3.2.3.2.1 Trim.** The following trim margins shall be provided as a minimum in transition,

Longitudinal - **20** percent of the "nominal" hover pitch control moment both under **all** engine operation (normal) and **one** engine out (emergency).

- NOTES: 1.) Step Control Input  
2.) AGARD 408 Damping (rate) Available

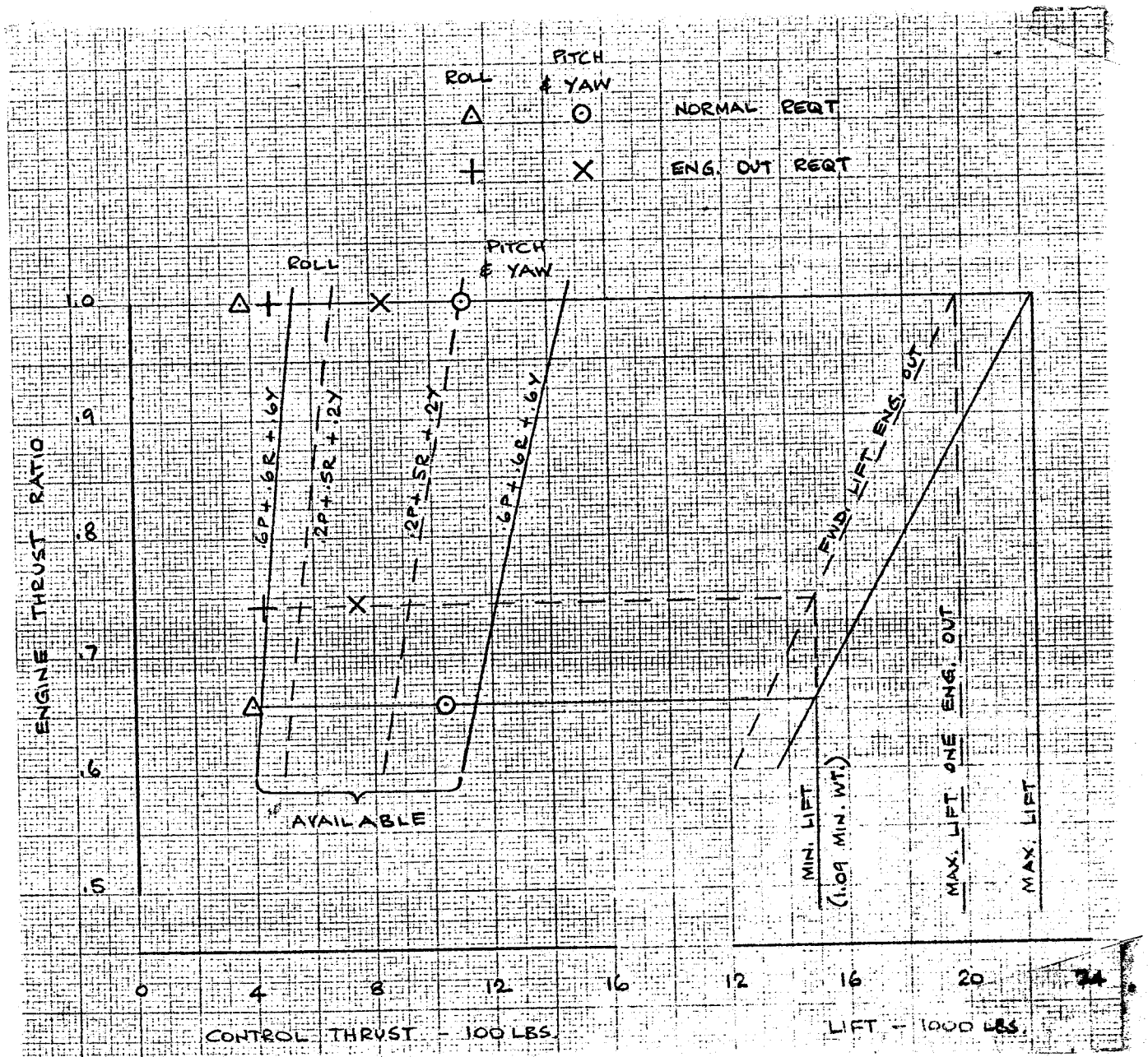


FIGURE 3-17. SIMULTANEOUS CONTROL THRUST AVAILABLE AND REQUIRED  
N309

- Lateral - 50 percent of the "nominal" hover roll control moment after trimming out an engine failure or a maximum side slip angle equivalent to a 35 knot sidewind or 15 degrees, whichever is larger.
- Directional - 20 percent of the "nominal" hover yaw control moment after trimming out an engine failure or a maximum side slip angle equivalent to a 35 knot sidewind or 15 degrees, whichever is larger. The nominal control powers are as discussed in 3.3.2.2.2.1 above.

Compliance with these requirements is demonstrated in Figures 3-18, 3-19, 3-20, and 3-21 for a full power accelerating transition. This is the most severe case longitudinally, since all the moment contributions act in the same sense, nose up, namely vectored thrust (aft) and the jet induced effects. In comparison, in a decelerating transition the thrust is vectored forward producing a relieving nose down pitching moment.

The 35 knot sidewind or  $\beta = 15^\circ$  (whichever is larger) is a more critical case than an engine failure in the lateral or directional plane.

**3.3.2.3.3 Conversion.** Conversion from thrust borne flight to pure wing borne flight or vice versa, shall not result in any objectionable or uncontrollable aircraft motion.

Conversion to wing borne flight was investigated at 180 knots. The moment input is composed of two parts, a step diverter valve change from lift to cruise position and two seconds later, the shut off of all lift engines. The changes in aerodynamic interference moment associated with the above are included. The time constant of the diverter actuation is 0.05 seconds, while the throttle-engine lag is 0.5 seconds. No pilot stick corrections were applied which correspond to the most severe aircraft response. The input moments and the resulting airplane motions with SAS on and off are shown in Figure 3-22. With SAS off, the initial pitch angle overshoot is less than 6 degrees which is reduced to less than 3 degrees with SAS on.

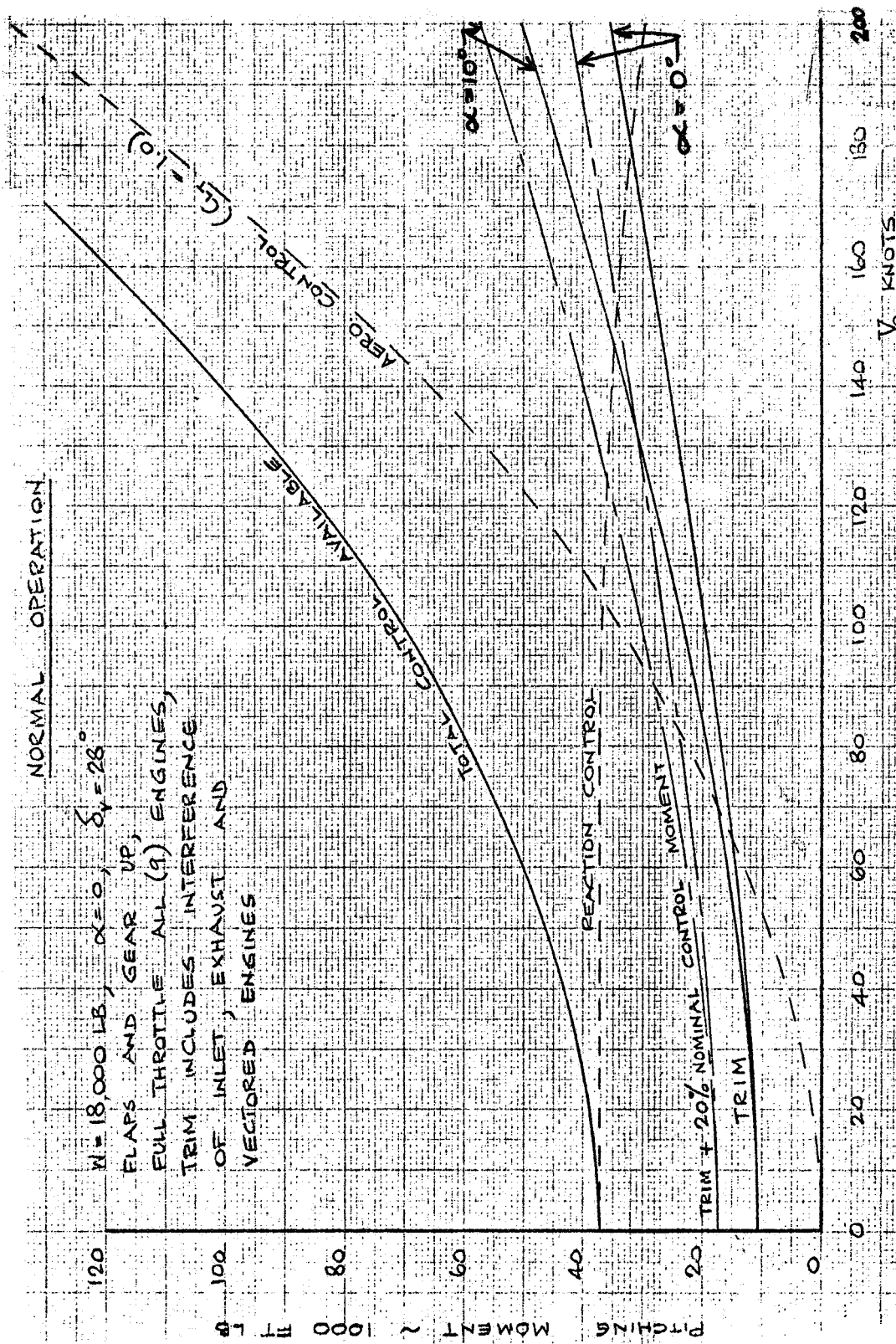


FIGURE 3-18. STABILITY AND CONTROL - TRANSITION PITCH CONTROL - N-309 - COMPOSITE MODE

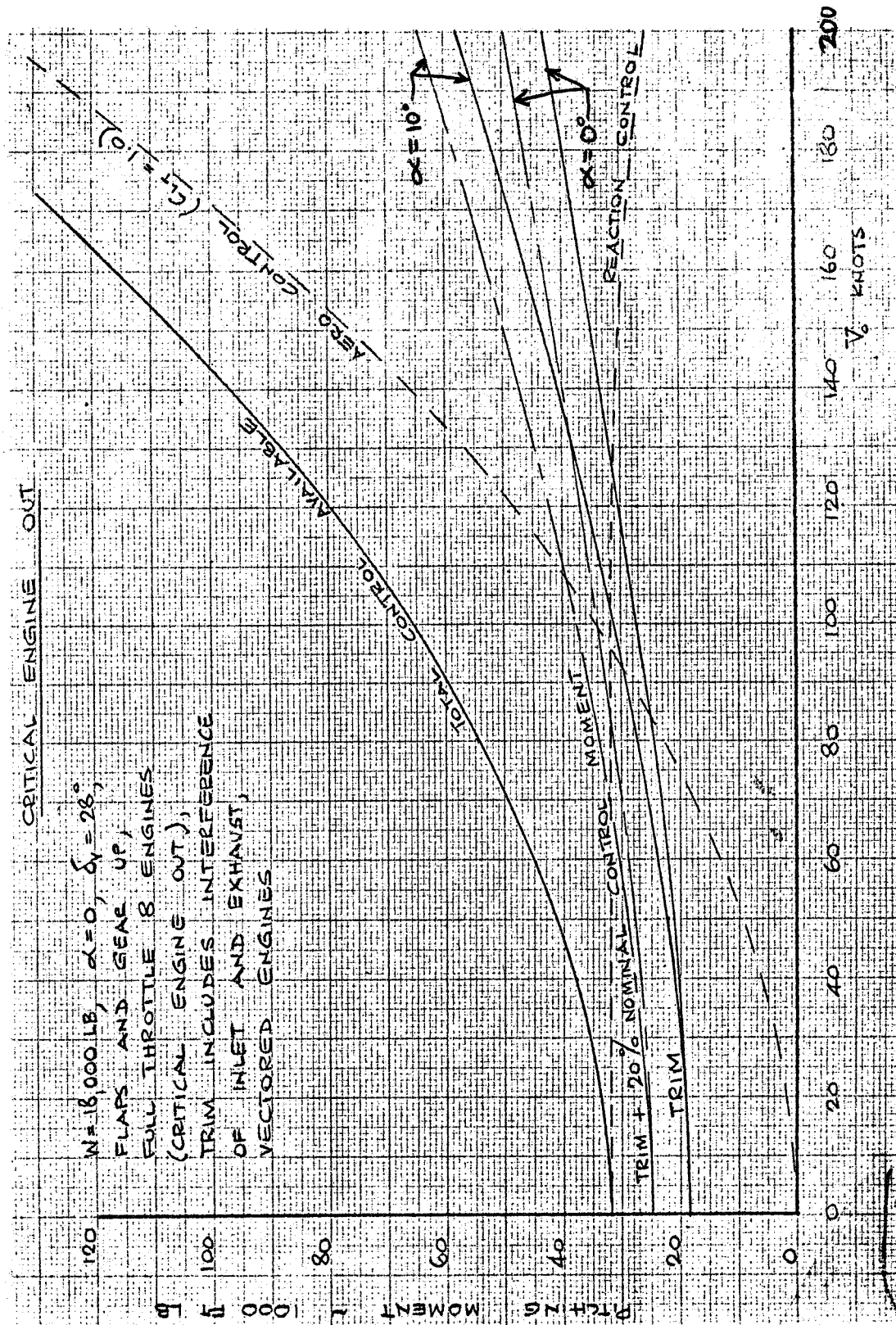


FIGURE 3-19. STABILITY AND CONTROL - TRANSITION PITCH CONTROL - N-309 - COMPOSITE MODE

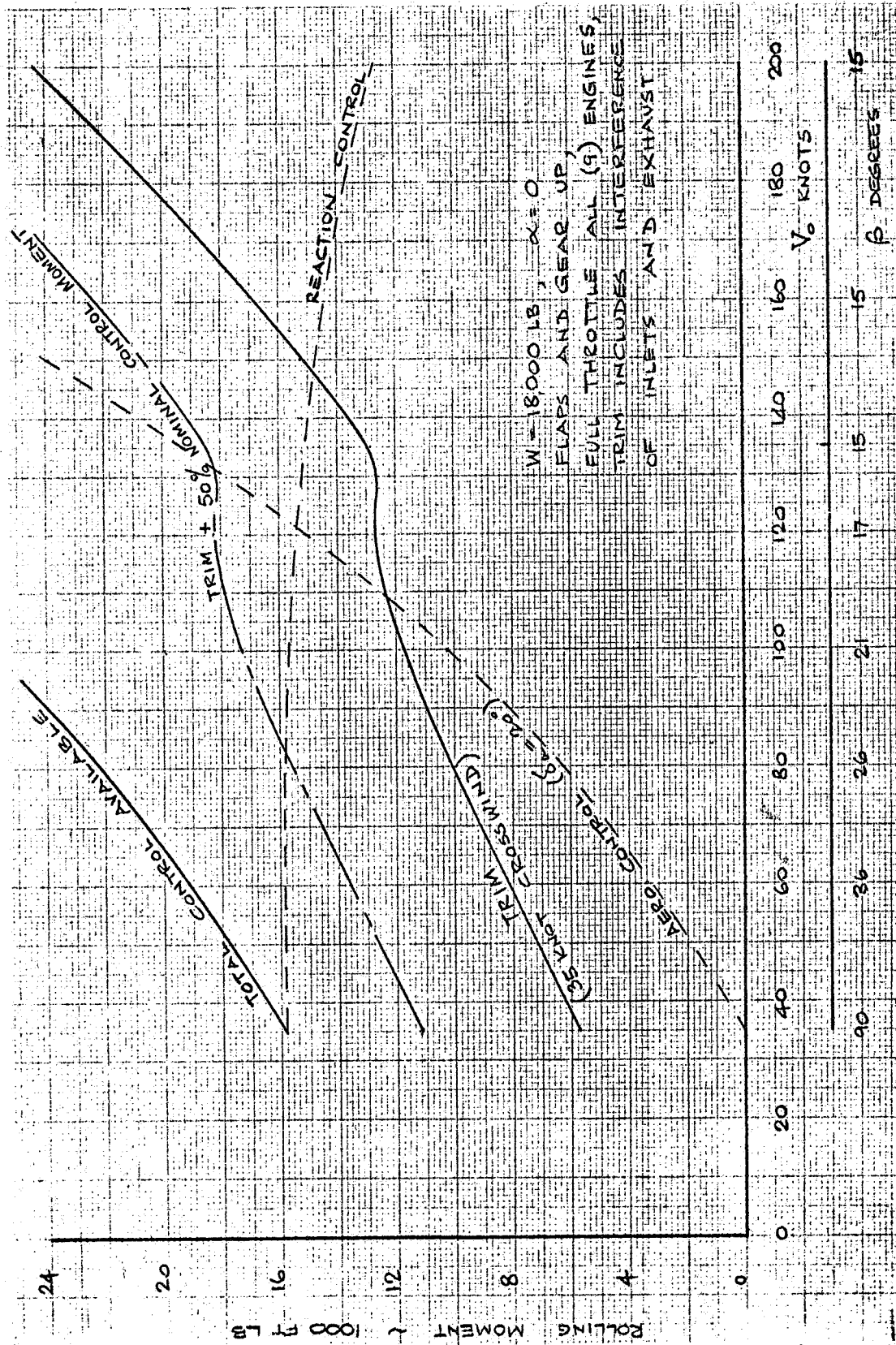


FIGURE 3-20. STABILITY AND CONTROL - TRANSITION ROLL CONTROL - N-309 - COMPOSITE MODE

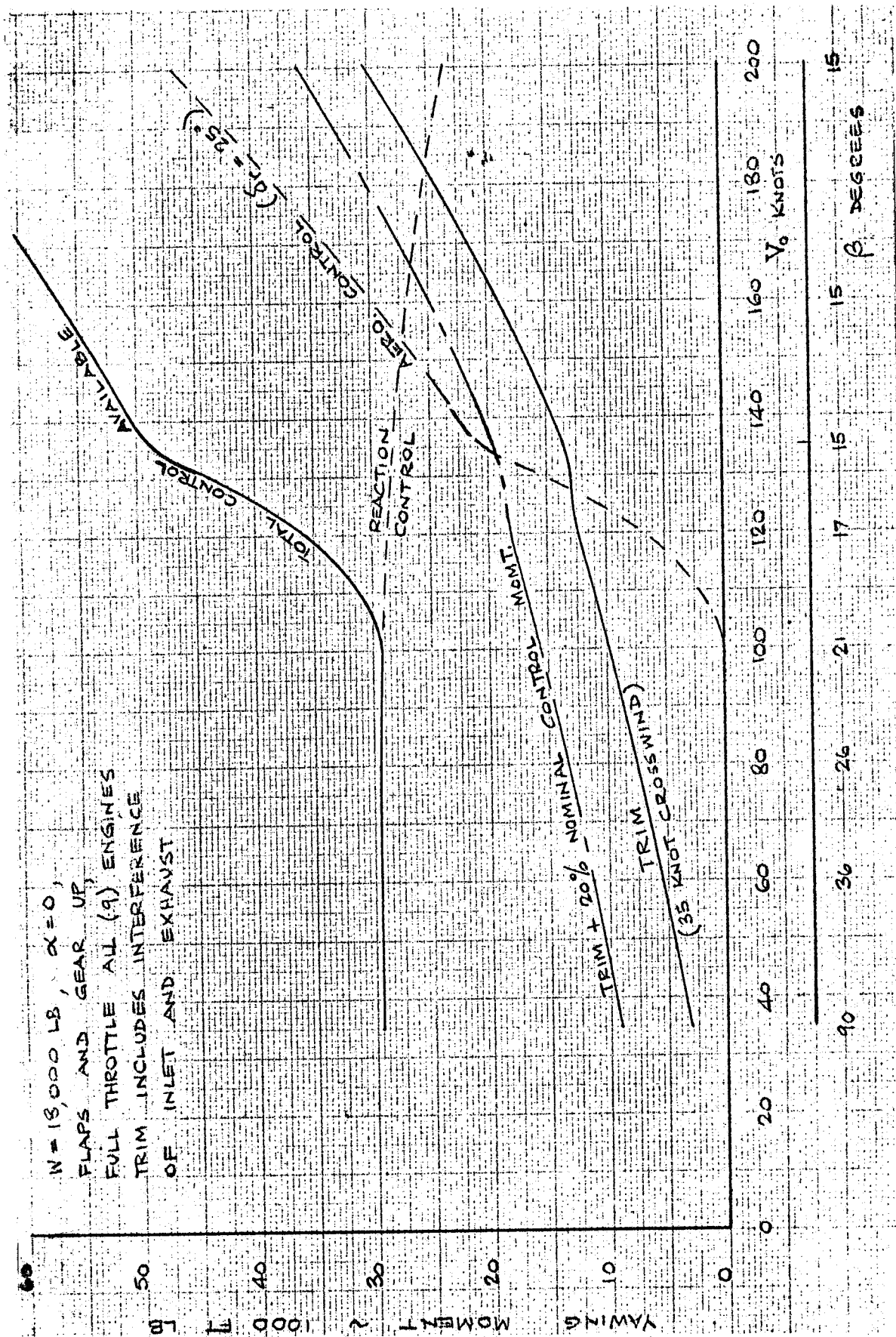


FIGURE 3-21. STABILITY AND CONTROL - TRANSITION YAW CONTROL - N-309 - COMPOSITE MODE

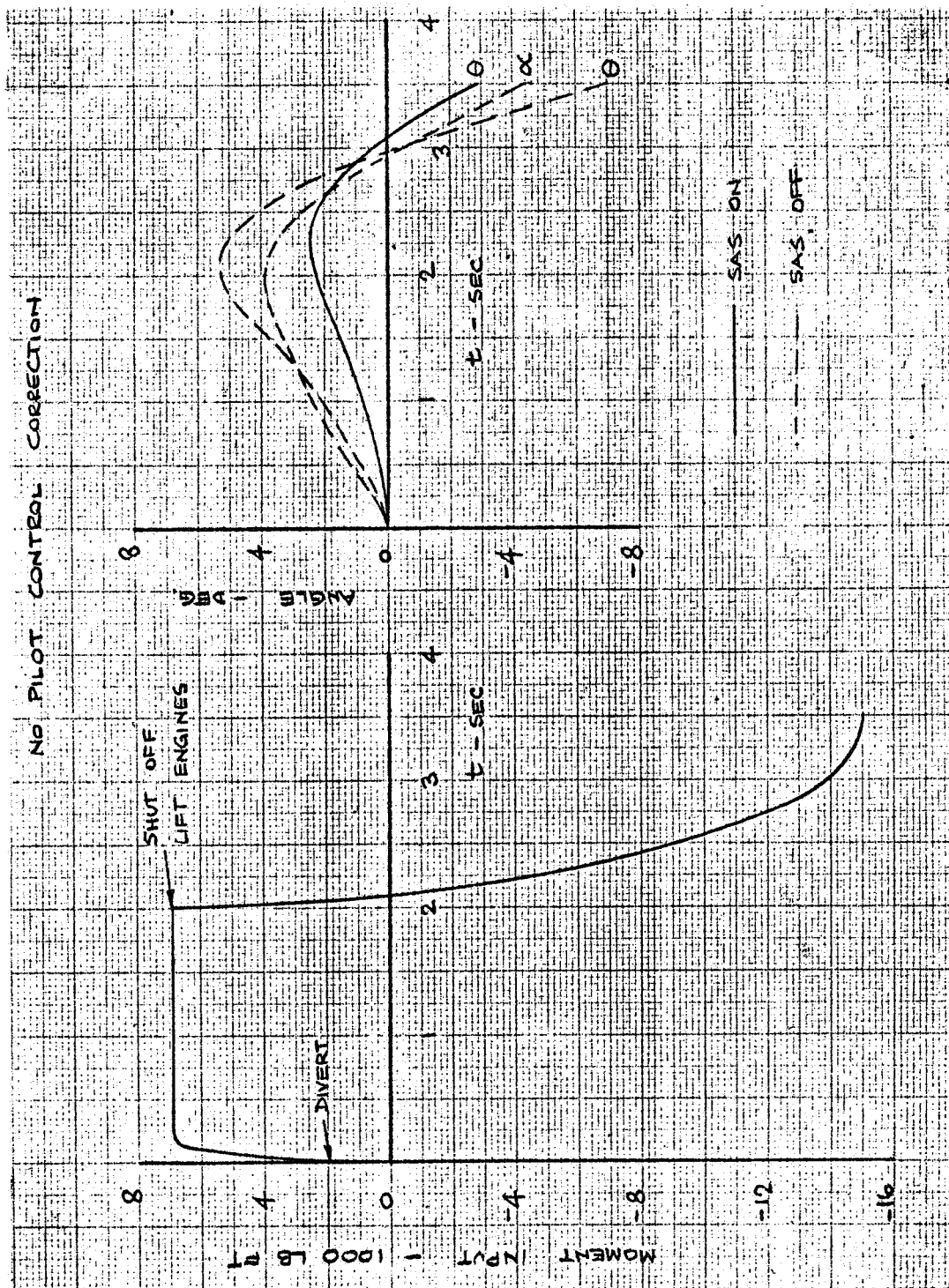


FIGURE 3-22. CONVERSION DYNAMICS - N-309 - COMPOSITE MODE

### 3.3.3 Flutter Characteristics

The aircraft and all ~~its~~ components shall be free from divergence, flutter, buzz or other aeroelastic instability within the flight and weight envelopes herein defined.

### 3.4 STRUCTURAL DESIGN CRITERIA

The structural design criteria shall be based on the applicable portion of the MIL-A4860 (ASG) series military specifications. In cases where a MIL-A-8860 (ASG) requirement is considered too severe the requirement shall be modified and restrictions placed on the aircraft provided the restrictions do not compromise the basic mission of the aircraft. The load factors and speeds shall be selected consistent with maintaining the strength level of the aircraft to preserve the structural design to the maximum degree consistent with the Flight Research Mission Requirements.

The service life of the aircraft shall be as follows:

Design of any new primary structure of the aircraft will be on a fail-safe basis to the maximum extent feasible. Structural design will be based on a minimum service life of 300 hours with a scatter factor of 4.0 distributed in the following manner:

- (a) 100 hours in conventional flight cruise at 6,000 feet altitude.
- (b) 100 hours at climb speed at 3,000 feet altitude.
- (c) 100 hours at transition speeds at 3,000 feet altitude and below.
- (d) 40 routine maneuvers per hour shall be included.
- (e) 4 V/STOL landings and transitions per flight hour shall be assumed.
- (f) Compatible life shall be established for components such as control surfaces, doors, etc.

#### 3.4.1 Limit Flight Load Factors

The aircraft shall be designed to limit maneuver load factors of 3.75 g and -1.5 g. In-flight operation of the aircraft will be restricted to 80 percent of these load factors (refer to Figures 3-23 and 3-24). To avoid excessive loads resulting from atmospheric turbulence, the following criteria shall apply:

- (a) Speed restrictions shall be determined so that the loads resulting from a 50 fps vertical ***gust*** ( $U_{d_e}$ ) do not exceed the allowable operating loads.
- (b) Using the maneuver speed envelopes, the allowable ***gust*** velocities shall be determined based on the allowable operating loads.
- (c) The speed restrictions imposed by Item 1 must result in an adequate operating envelope to satisfy the primary objectives of the research vehicle.

#### 3.4.2. Landing Load Factors

The structure shall be designed to the loads resulting from conventional and vertical landings. The method of analysis and criteria of MIL-A-8862 (ASG) shall be used where applicable.

The following landing conditions shall be used for design of the aircraft:

- (a) Conventional landing - 12 fps sink speed with 1.0 g lift and **Maximum** Design Landing weight of 18,000 pounds.
- (b) VTOL landing - 15 fps sink speed with 2/3 hovering thrust and Maximum Design Landing weight of 18,000 pounds. The following conditions shall be considered.
  - (1) The aircraft structure (except for the landing gear) shall be designed for a 15 fps sink speed with a side velocity of 5 knots. The landing gear itself shall be designed to the helicopter obstruction requirements of MIL-S-8698 at 15 fps vertical sink speed.
  - (2) Structure and landing gear shall be capable of withstanding the loads produced by a VTOL sink speed of 10 fps with the aircraft in a 10 degree banked attitude.

### 3.4.3 Design Speeds

The structural design and operating speeds are shown in Figures 3-19 and 3-20 and are tabulated below:

Maximum Structural Design Level Flight Speed	--- 450 KEAS as limited by Mach = 0.80
Maximum Structural Design Limit Airspeed	--- 450 KEAS as limited by Mach = 0.80
Maximum Flap Design Airspeed ( $V_{LF}$ ) Maximum Landing Gear Operating Speed Maximum Lift Engine Operating Speed	--- 220 KEAS
Maximum Demonstration Speed ( $V_L$ )	--- To be determined by gust analysis.

All structural components including windshields and miscellaneous fairings, shall be designed to the airspeeds of Figure 3-19, as applicable.

### 3.4.4 Center of Gravity Limits

The center of gravity limits for flight shall be 10 percent MAC to 23 MAC.

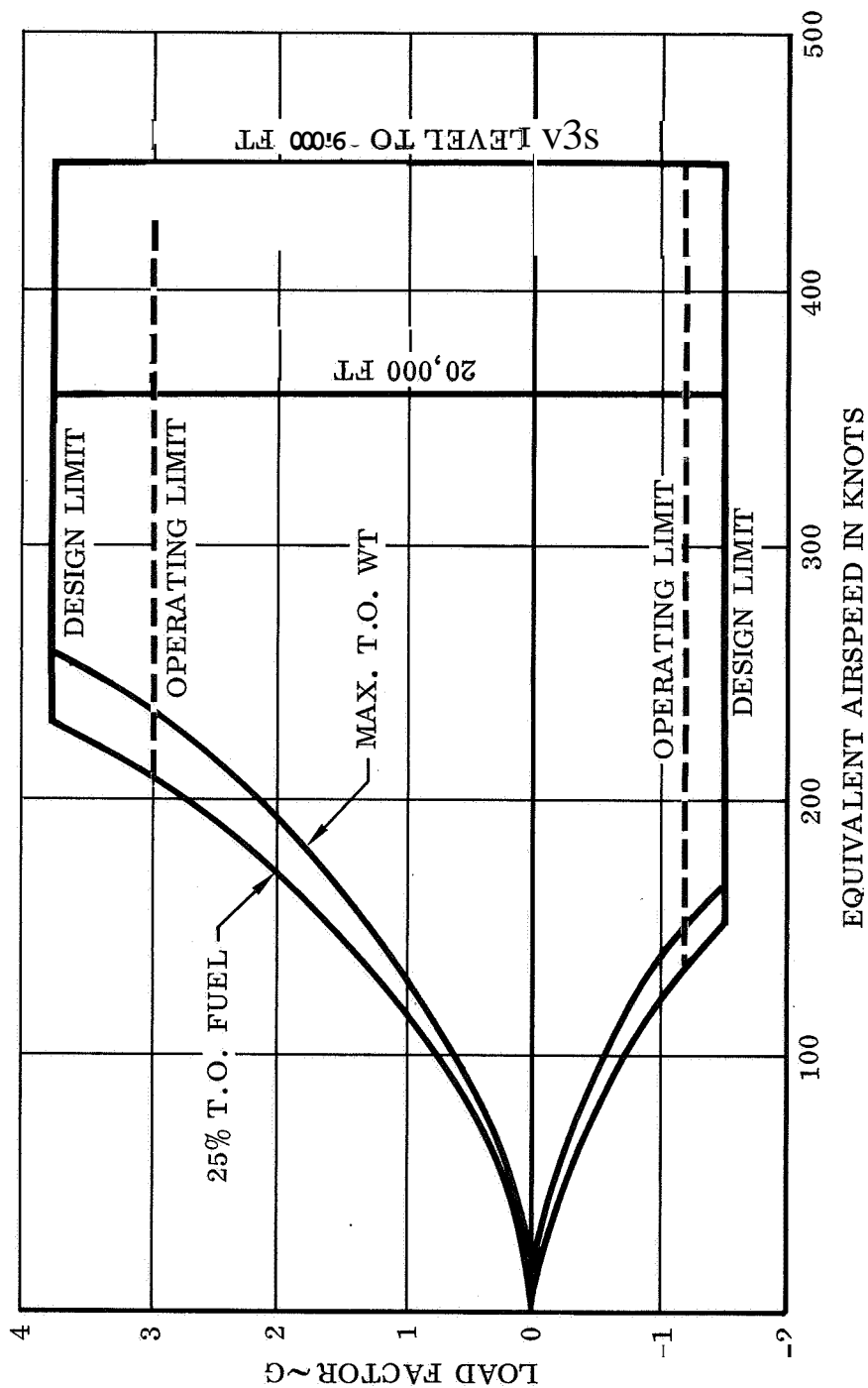
## 3.5 WINGGROUP

### 3.5.1 Description and Components

The wing shall be a full cantilever all-metal structure, consisting of a basic box beam structure, leading edge and trailing edge flaps, ailerons and lateral reaction jet controls at the wing tips. The wings shall be removable from the fuselage for surface and air transportability.

### 3.5.2 Construction

The basic structure of the main wing **box** shall consist of a two-spar multirib type construction with upper and lower stringer stiffened covers utilizing aluminum or titanium alloy material. An auxiliary spar at approximately 70 percent of the chord shall be used to mount the trailing edge flaps and ailerons.



NOTES:

1. SPEED LIMIT OF 450 KEAS FROM SEA LEVEL TO 9,000 FEET AND 0.80 MACH ABOVE 9,000 FEET.
2. GUST LIMITS TO BE DETERMINED AS SPECIFIED IN DESIGN CRITERIA.
3. UNSYMMETRICAL LIMITS = 0.8 N<sub>z</sub> SYMMETRICAL.

FIGURE 3-23. DESIGN AND OPERATING LIMITS FOR SYMMETRICAL MANEUVER

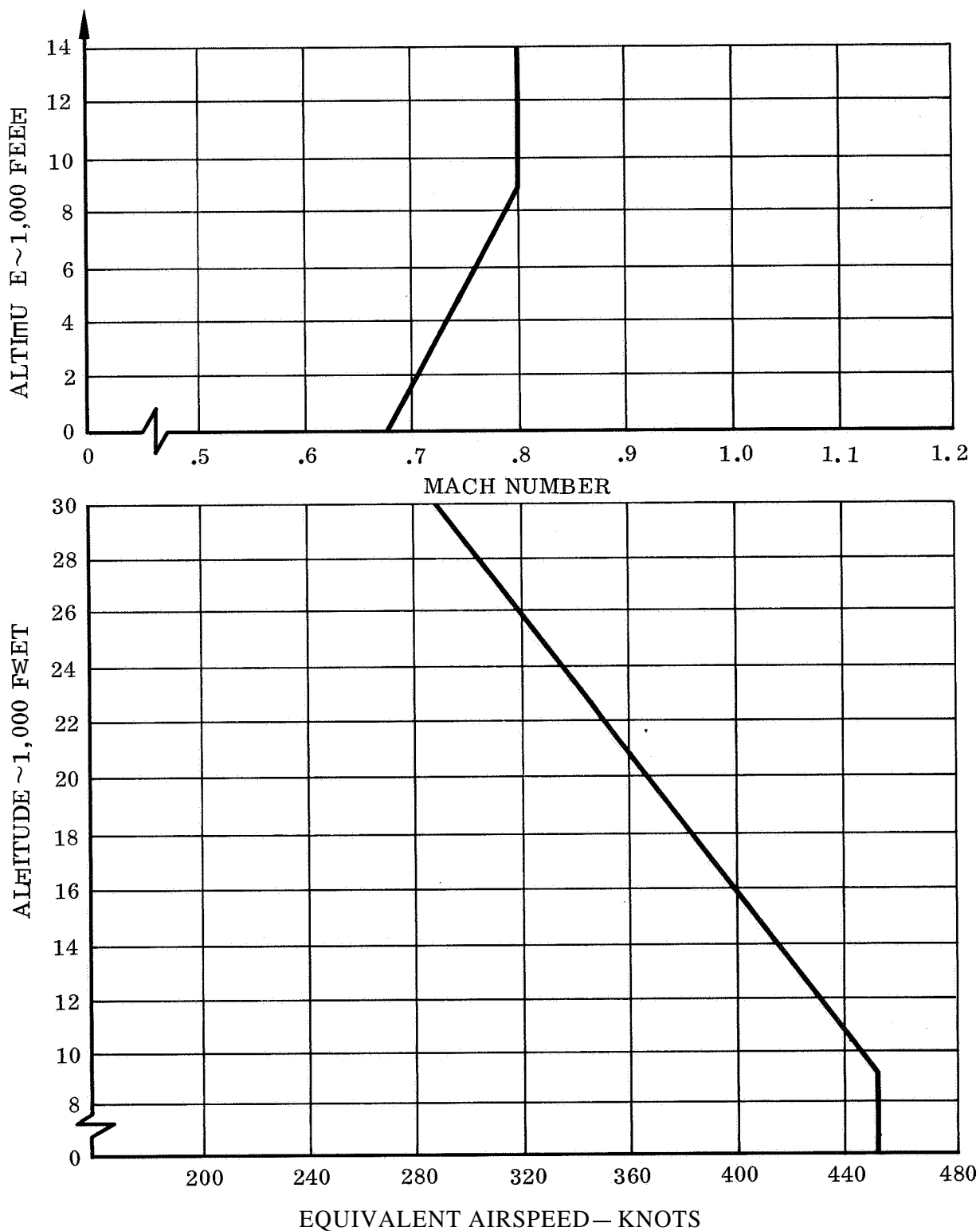


FIGURE 3-24. MAXIMUM MACH AND EQUIVALENT AIRSPEED VS. ALTITUDE

The center section shall consist of a box structure consisting of front and rear spars and stringer stiffened covers. Both front and rear spars and covers shall be spliced at the wing trunnion attaching ribs. The wings shall be attached to the fuselage by four bolts connecting the wing trunnion ribs to four trunnion fittings mounted on the fuselage structure. See Drawing AD4501 (Figure 3-25).

**3.5.2.1 ACCESS AND INSPECTION PANELS.** Access openings shall be provided in the wing to permit inspection and maintenance of functional components and structure.

### **3.5.3 Ailerons**

The ailerons shall be of conventional design and construction utilizing aluminum alloy material. The aileron shall be hinged, utilizing piano type hinge, with the hinge line lying within the airfoil contour. The ailerons shall be adequately balanced statically and dynamically.

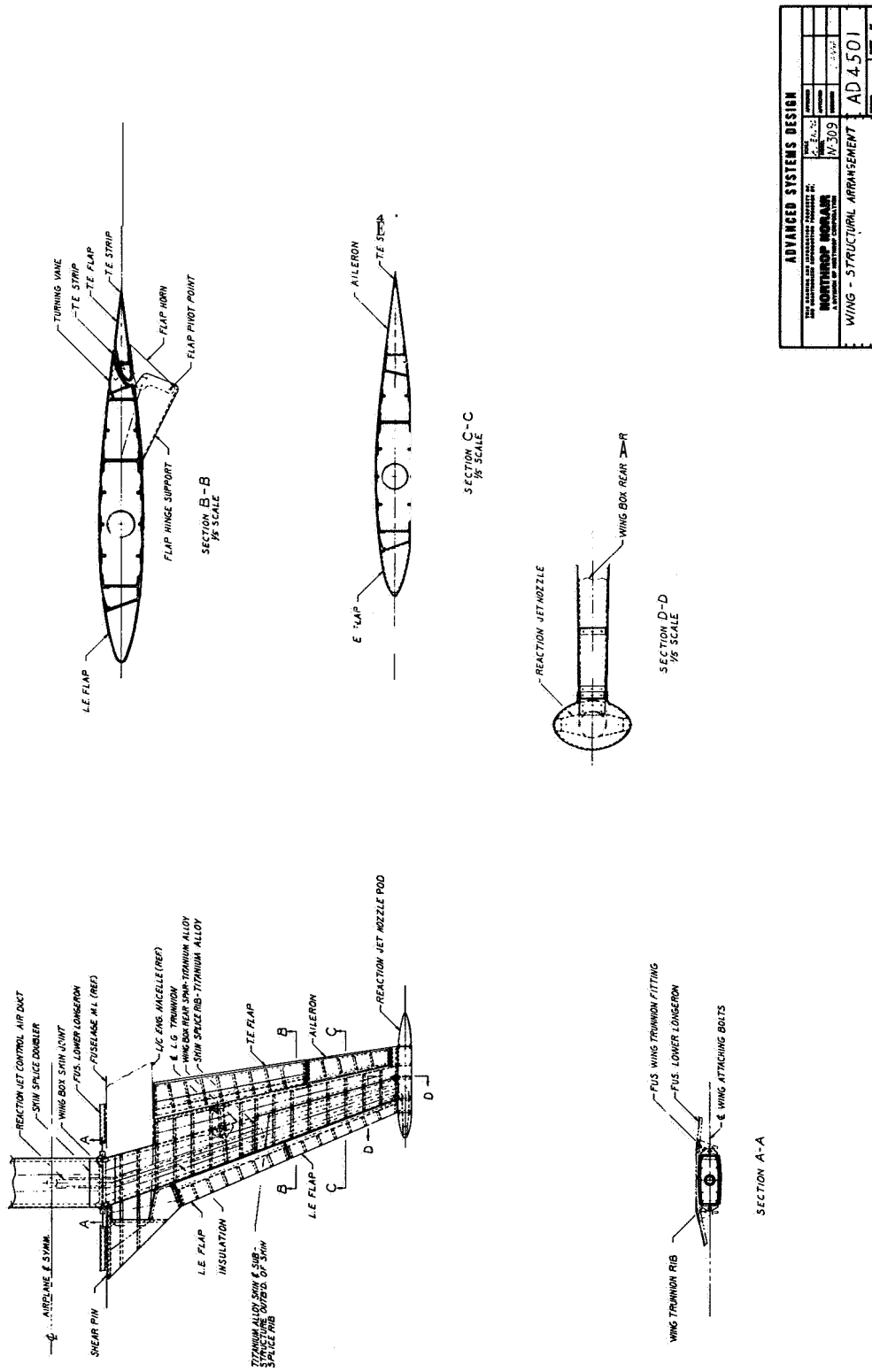
### **3.5.4 Lift and Drag Devices**

**3.5.4.1 T.E. FLAPS.** Externally hinged flaps shall be incorporated in the wing trailing edge outboard of the nacelles, extending to the inboard ends of the ailerons. Piano hinged turning vanes shall also be incorporated for maintaining the proper airflow over the flaps. The flaps and turning vanes shall be of conventional design and construction utilizing aluminum alloy material. The flaps shall be hinged on anti-friction bearings and actuated by electric power.

**3.5.4.2 L. E. FLAPS.** Piano hinged **flaps** shall be incorporated in the wing leading edges outboard of the wing L. E. fairing, extending to the inboard side of the, reaction control nozzle fairing at the **wing** tip. The **flaps** shall be of conventional design and construction utilizing aluminum alloy material. The flaps shall be actuated by electric power.

### **3.5.5 Wing Tip Bullet Fairing**

The wing tip fairing housing the roll control nozzle shall be of conventional skin and former construction, utilizing heat resistant alloy material in high structural temperature areas and aluminum alloy material in areas where structural temperatures are not expected to exceed 220 F.



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NORTHROP MODEL 309	AD 4501		
WING - STRUCTURAL ARRANGEMENT			

FIGURE 3-25

### 3.6 TAIL GROUP

#### 3.6.1 Description and Components

The tail group shall consist of a cantilever fin mounting a rudder assembly and a movable horizontal stabilizer, fuselage mounted. See Drawing AD 4502 (Figure 3-26).

#### 3.6.2 Stabilizer

The basic structure of the stabilizer shall consist of a monospar multi-rib type of construction with stringer stiffened covers utilizing aluminum alloy material. Stabilizer assemblies shall be right and left, integrally connected by means of torque tubes, splicing at the centerline of the airplane. The stabilizer torque tubes shall be supported at the side of the fuselage by means of anti-friction type of ball bearings. The stabilizer shall be actuated by hydraulic power.

#### 3.6.3 Elevator

Not applicable.

#### 3.6.4 Fin

The fin structure shall be a multi-spar, multi-rib type of construction with stiffener reinforced covers, utilizing aluminum alloy material. Structural provisions shall be incorporated for attaching the fin spars to the aft fuselage substructure. Access shall be provided to allow inspection of all structural components and to permit inspection and maintenance of rudder control components. A non-metallic tip cap shall be provided for housing the UHF antennas.

#### 3.6.5 Rudder

The rudder structure shall consist of front spar, trailing edge strip, end closure ribs and skin covers all bonded to a honeycomb core. All materials shall be of aluminum alloy. Rudder hinges shall incorporate anti-friction type of ball bearings. The rudder shall be adequately balanced statically and dynamically.

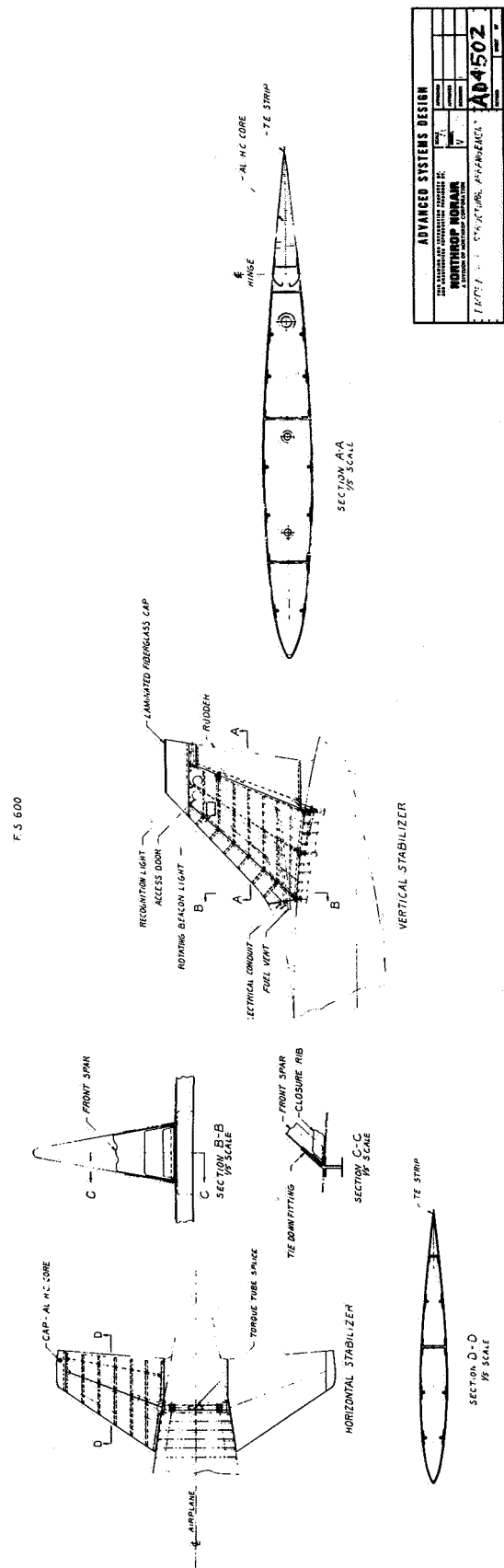


FIGURE 3- 6

### 3.7 BODY

The body group shall consist of the fuselage structure and all integral provisions for the attachment of the wing, empennage, installation of the lift engines, lift/cruise engine nacelles, crew compartment, subsystems, fuel and equipment. See Drawing AD 4500 (Figure 3-27).

#### 3.7.1 Fuselage

**3.7.1.1 DESCRIPTION.** The arrangement of the fuselage shall consist of a nose section incorporating the flight test boom and pitch/yaw control nozzle; a forward section housing the crew compartment, nose landing gear and equipment and/or payload; a center section housing the lift engines, fuel cells, wing carry-through structure and attaching structure for the lift/cruise engine nacelles, and an aft section supporting the empennage structure, tail bumper, pitch/yaw control nozzle fairing and housing fuel cells and additional equipment and/or payload.

**3.7.1.1.1 Design Provisions for Installation of Thrust Reversers.** Thrust reversers will not be installed for aircraft delivery; however, structural capability shall be incorporated into the L/C engine nacelles to accommodate the installation and loads due to operation of thrust reversers. Some modification of the existing tail pipe and aft nacelle fairing will be required at the time the thrust reversers are installed.

**3.7.1.1.2 Design Provisions for Direct Lift Mode Operation.** Design provisions shall be incorporated into the rear lift engine bay to minimize modification of the existing structure, control air ducting and affected subsystems as required to accommodate a direct lift mode configuration.

**3.7.1.2 CONSTRUCTION.** The basic structure shall consist of upper and lower longerons, side skin panels and vertical frames between longerons. The intermediate bulkheads shall divide the engine bay into four compartments for housing two lift engines in each of the forward three compartments and one lift engine plus the lift exhaust nozzles from the L/C engines in the aft compartment. Supporting structure between bulkheads shall be provided for attaching the lift engine support trunnions and a vertical longitudinal firewall between each engine. Vertical frames and intercostals shall be spaced so as to minimize acoustically induced fatigue failure of the skins. Removable access panels shall be provided to permit entry to critical engine controls

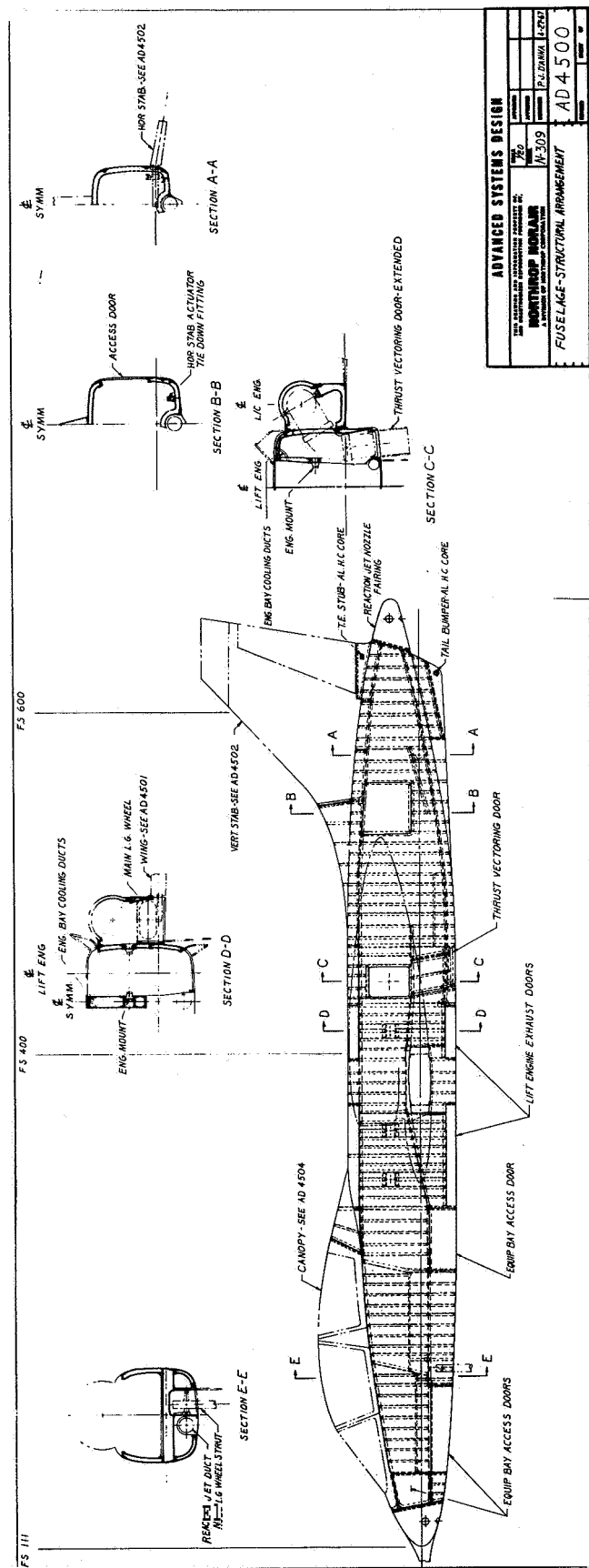


FIGURE 3-27

and plumbing. A suitably reinforced opening shall be provided on each side of the fuselage body to provide entry for the lift cruise engine diverter valve exhaust nozzles. The fuselage shall not be designed for internal pressurization.

The major portion of the skins and fuselage substructure shall be constructed from aluminum alloy. Firewalls, pitch/yaw control ducting and nozzle fairings, thrust vectoring doors for the L/C engines and local structure where temperatures may exceed 200 F shall be constructed from stainless steel alloy or other heat resistant alloys. The trailing edge stub for the rudder and energy absorbing portion of the tail bumper may be of aluminum honeycomb core sandwich construction.

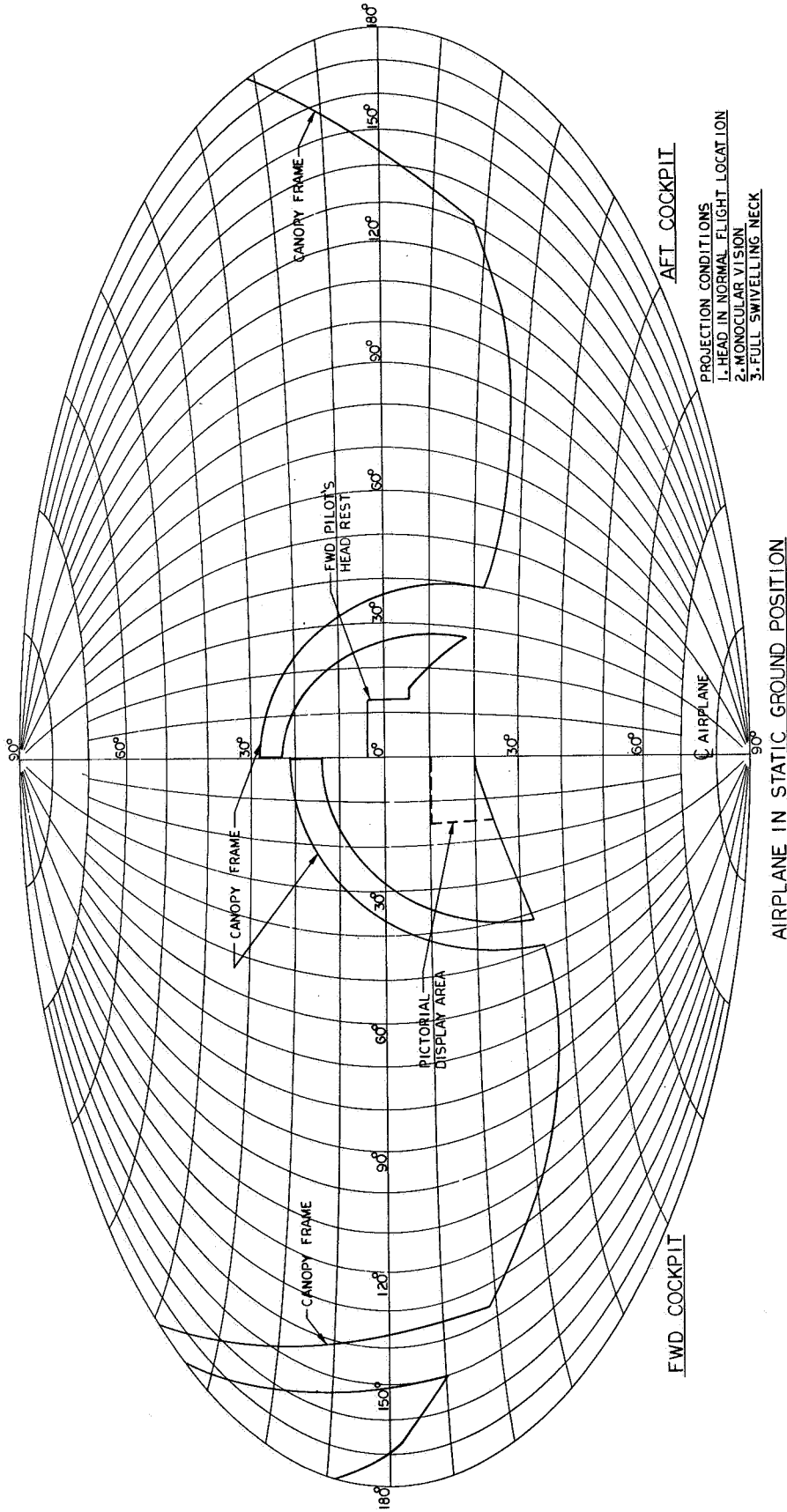
**3.7.1.3 CREW STATIONS.** Facilities for the test pilot and safety pilot, in a tandem seating arrangement, shall be included in the forward section of the fuselage. Light-weight ejection seats, capable of safe ejection of the crew through closed canopies, at any combination of speed and altitude within the approved flight envelope, including zero-zero, shall be provided.

**3.7.1.3.1 Windshield.** A contoured, one-piece windshield for the forward cockpit and a one-piece flat panel windshield for the aft cockpit shall be provided. The aft windshield shall be designed to protect the aft crewman from the rocket blast exhaust resulting from ejection of the forward seat. All transparent panels shall be fabricated of bi-axially stretched Plexiglas. Visibility within the hemisphere of each crew member shall present minimum obstruction.

**3.7.1.3.2 Canopy.** The cockpit enclosure shall have two one-piece canopies, one for each crewman. Each canopy shall be hinged along the right hand edge of the cockpit opening to provide easy access to the crew stations. Individual locks and handles shall be provided on the left side of each canopy. Positive latching from without and within shall be provided. The area in line with the ejection path of the crew seats shall contain no metal framework, to permit safe ejection through the canopy. All transparent panels shall be fabricated of bi-axially stretched Plexiglas. See Drawing **AD 4504** (Figure 3-28).

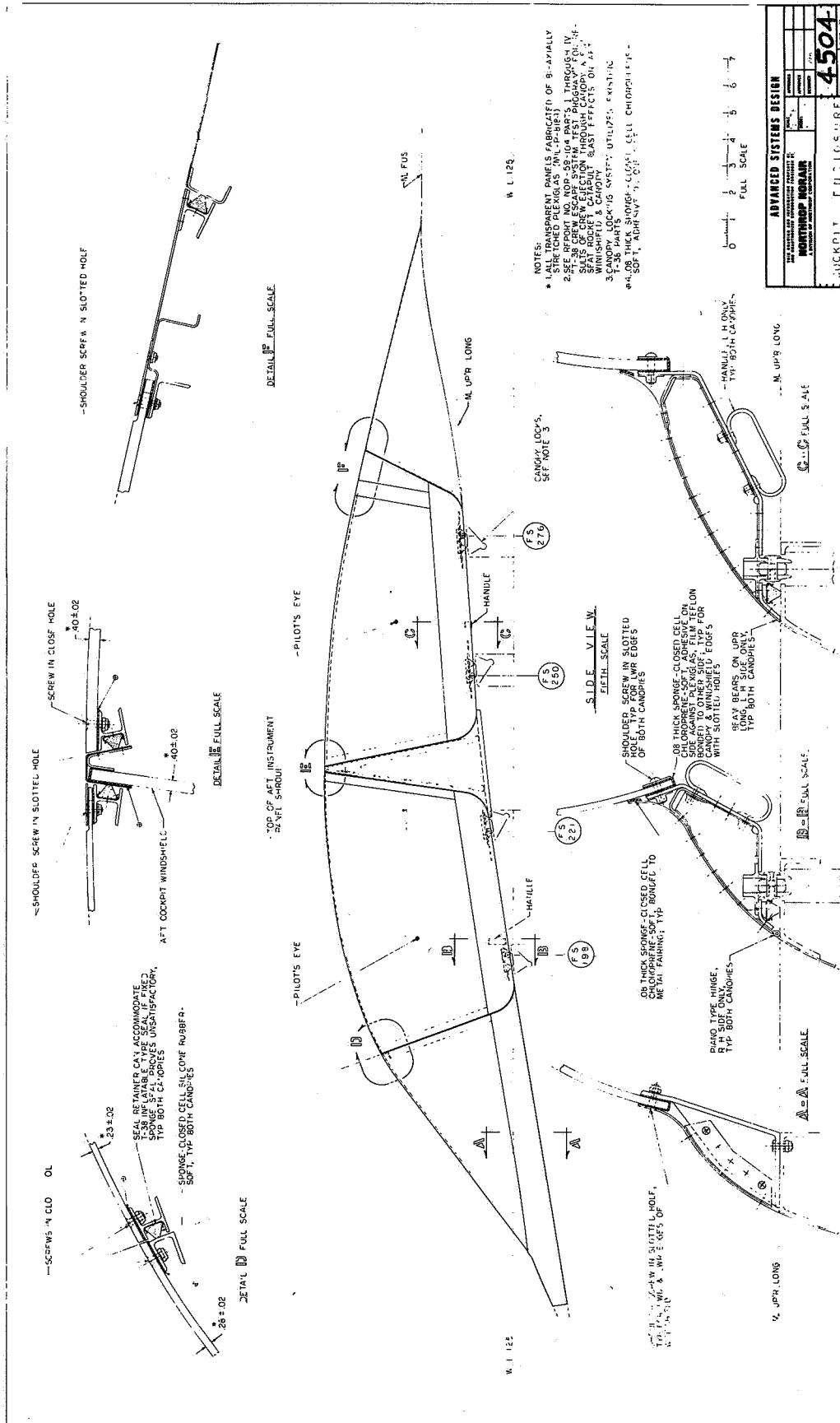
**3.7.1.3.3 Visibility.** The visibility for this configuration is as presented in Figure 3-28A.

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VTOL TANDEM COCKPIT VISIBILITY (N-300)



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**3.7.1.4 EQUIPMENT COMPARTMENT.** Compartments shall be provided for the installation of electronic and other equipment and/or payload in the forward, center and aft fuselage sections of the fuselage body.

**3.7.2 L/C Engine Nacelle**

**3.7.2.1 DESCRIPTION.** The arrangement of the L/C engine nacelles shall consist of a nose section housing the air inlet duct and structurally mounted accessory drive gear box, a center section housing the engine and accessories and an aft fairing housing the exhaust tail pipe.

**3.7.2.2 CONSTRUCTION.** The basic structure shall consist of upper and lower longerons, skin panels with frames and intercostals spaced so as to minimize acoustically induced fatigue failure of the skins. The upper portion of the nacelle, in the vicinity of the engine, shall be removable to permit engine installation and/or removal. Other access doors shall be provided for the servicing of critical engine accessories. Firewalls shall be provided to isolate the engine from the fuselage structure. Structural provisions shall be provided for mounting the engine in the nacelle and attaching the nacelle to the fuselage.

The skins and major portion of the nacelle substructure shall be constructed from aluminum alloy. Firewalls, tailpipes and diverter valve exhaust nozzles shall be made from stainless steel or other heat resistant alloys.

**3.8 ALIGNING GEAR SYSTEM**

**3.8.1 Aligning Gear**

The aligning gear system shall consist of the main landing gear and the nose landing gear, in a tricycle arrangement. See Drawing AD 4495 (Figure 3-29).

**3.8.2 Main Landing Gear**

The main landing gear system shall consist of right and left hand assemblies. Each unit shall incorporate an oleo-pneumatic shock absorber.

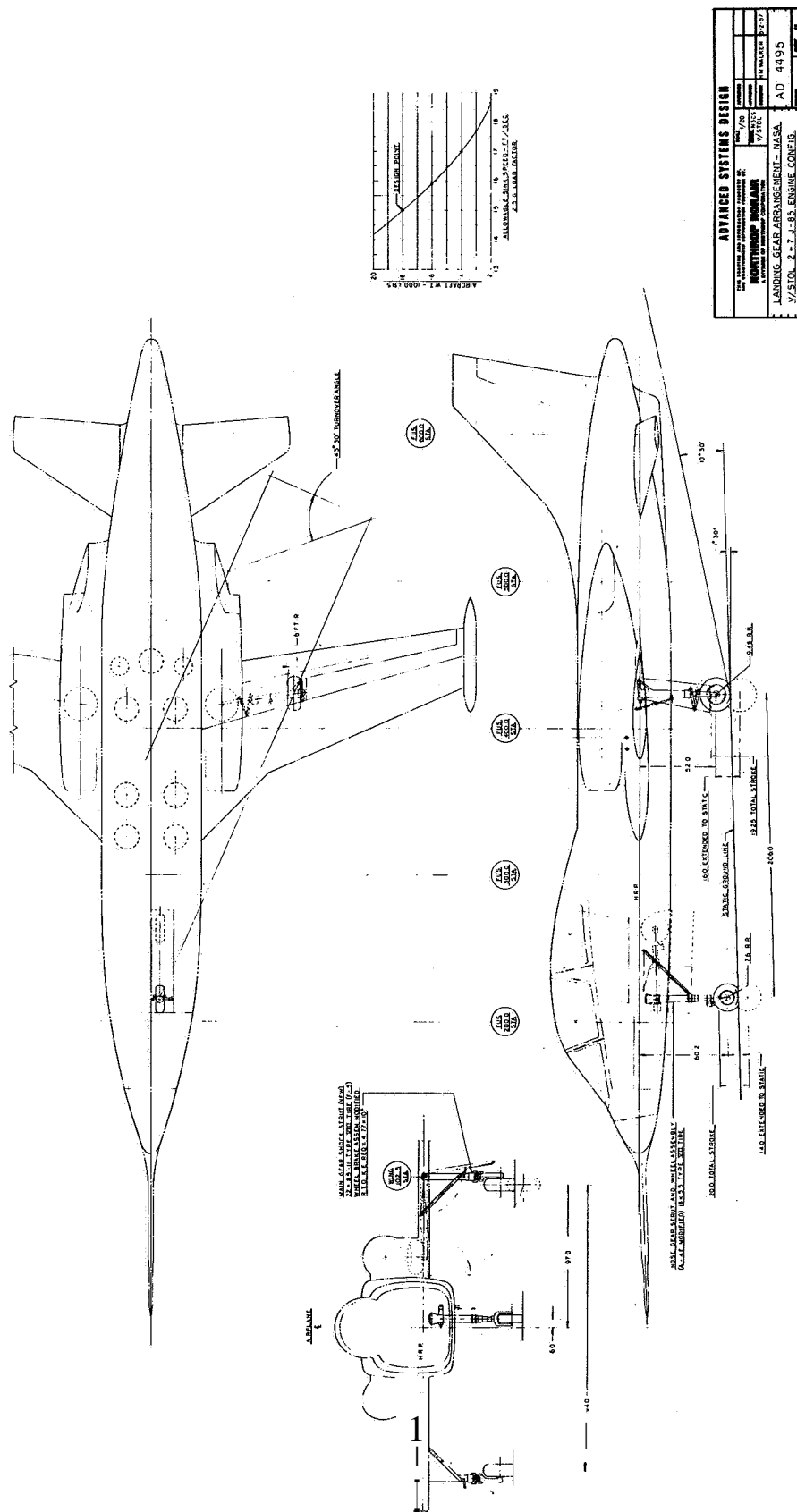


FIGURE 3-29

3.8.2.1 WHEELS, BRAKES, AND BRAKE CONTROL SYSTEMS. Each main landing gear shall be equipped with the Northrop F5 tire, wheel and brake assembly. The tires shall be 22 x 8.5-11, Type VIII, tubeless.

3.8.2.2 BRAKES. The brakes shall be actuated by hydraulic power, reverting to manual pressure when hydraulic power is not available. Parking brake provisions will be made.

3.8.2.3 RETRACTING, EXTENDING AND LOCKING SYSTEM. Each main unit shall be hydraulically actuated from retracted to down and back, and shall be equipped with up and down locks. Emergency release and extension shall be provided.

### 3.8.3 Auxiliary Landing Gear (Nose Wheel)

3.8.3.1 NOSE LANDING GEAR, The nose landing gear system shall consist of a single nose wheel supported by a suitable oleo-pneumatic shock absorber incorporating suitable castering offset and a combined steering and shimmy damper unit.

3.8.3.2 WHEEL AND TIRE. The nose wheel, tire and shock strut shall be a modified A4E assembly. The tire size is 18 x 5.5, Type 7.

3.8.3.3 SHOCK STRUT. The nose landing gear shock strut shall be of the air-oil type and conform to the requirements of Specifications MIL-S-8552A and MIL-T-~~6053~~53A.

3.9 Not applicable.

### 3.10 FLIGHT CONTROL SYSTEMS

The flight control system shall consist of primary and secondary systems, controllable by either the evaluation or the safety pilot.

### 3.10.1 Primary Flight Control Systems

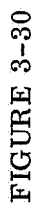
The primary flight control systems shall provide angular control of the airplane about all three axes throughout its speed range. See drawing AD 4498 (Figure 3-30).

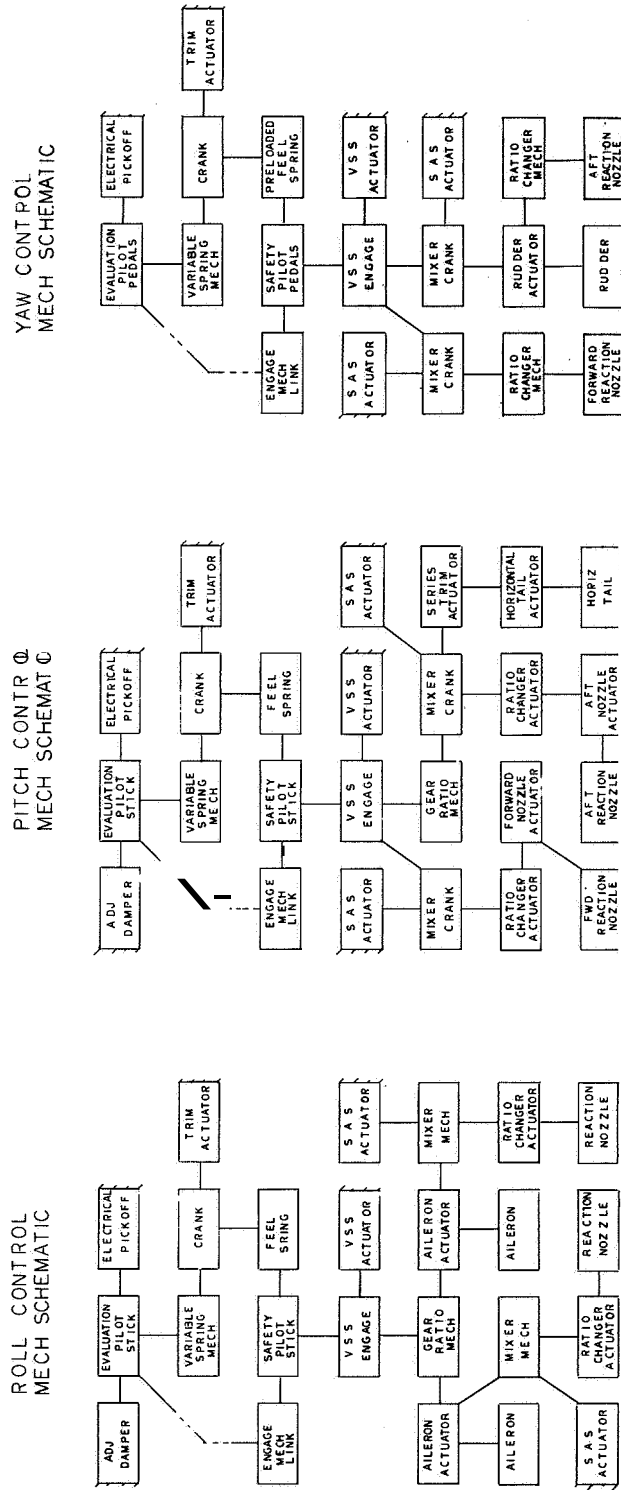
**3.10.1.1 FLIGHT STATION CONTROLS.** Angular control is provided through conventional control stick and pedals located in each cockpit in accordance with AFSCM 80-1. The evaluation pilot's control commands will be through electrical transducers, the safety pilot's control commands will be through conventional control cables, push rods and bellcranks to fully-powered dual-hydraulic surface and reaction jet nozzle actuators. The conventionally located throttle knobs control the engines rpm electrically. The outboard knob **will** be provided for the cruise engines and the inboard knob for all the lift engines. Thrust vector control shall be provided through switches installed on the inboard throttle knob. Detented positions shall provide manual feel of preselected thrust vector nozzle position in conjunction with a visual position indicator in each cockpit.

**3.10.1.2 ARTIFICIAL FEEL AND TRIM.** The forces felt by either pilot shall be artificially provided. The evaluation pilot's feel system shall consist of a variable gradient, variable preload spring and a ground-adjustable damper. The safety pilot's artificial feel system shall consist of a preloaded spring. The trim actuator shall interconnect the two systems so that they always trim to the same point. Roll and pitch trim control shall be by means of the trim button on the sticks or as programmed. The yaw control trim **will** be by means of switches located on the console. The variations provided in the evaluation pilot's feel system shall include, as a minimum, a 100 percent variation in the stick force gradient.

**3.10.1.3 POWER SOURCE.** Power shall be supplied to the reaction jet nozzles and the aerodynamic surfaces by means of a primary hydraulic system and a utility hydraulic system. Each system shall be supplied from pumps driven by each cruise engine. Failure of a pump or an engine will only degrade the control response slightly.

**3.10.1.4 LATERAL SYSTEM.** The lateral control system is depicted schematically in diagram AD 4518 (Figure 3-31). Throughout flight operation lateral stick motions shall produce appropriate motions of the ailerons. In hovering, and through transition, the bleed system shall be pressurized, and these motions shall then also control





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A DIVISION OF NORTHROP CORPORATION			
FLIGHT CONTROL		MECH SCHEMATIC	
		PAGE 7 OF 1	

FIGURE 3-31

differential valving of compressor bleed **air** on a demand basis through upward and downward pointing nozzles at each wing tip. The mechanical system shall consist of cable and/or pushrod controls from the aft cockpit extending to the ailerons and the wing tip roll control nozzles. Failure of the system in either wing shall not affect operation in the opposite wing. The **VSS** commands are transmitted electrically from the front cockpit. See Appendix III.

**3.10.1.5 DIRECTIONAL SYSTEM.** The directional control system is depicted schematically in diagram AD 4518 (Figure 3-31). Throughout flight operation, differential pedal motions shall produce appropriate deflections of the rudder and simultaneously control differential rotation of the pitch reaction nozzles at each end of the fuselage. The mechanical system shall consist of cable and/or pushrod controls from the aft cockpit to the rudder actuator and to the control units **of** the reaction nozzles. The **VSS** commands from the front cockpit are transmitted electrically. See Appendix III.

**3.10.1.6 LONGITUDINAL SYSTEM.** The longitudinal control system is depicted schematically in diagram AD 4518 (Figure 3-31). Throughout flight operation, longitudinal stick motions shall produce appropriate horizontal tail deflections and simultaneously control the opening and closing of downward pointing nozzles located at the forward and aft extremities of the aircraft. These nozzles shall receive bleed **air** from the engine compressors during hover and transition. The mechanical system shall consist of cable and/or pushrod controls from the cockpit to the horizontal tail actuators and to control the nozzle opening of the reaction controls.

**3.10.1.7 MECHANICAL INTERCONNECT.** Provisions shall be made for mechanically interconnecting the front cockpit primary controls with the manual system connected to the rear seat controls. The **VSS** shall be turned off on any axis so connected.

**3.10.1.8 MECHANICAL STOPS.** Provisions shall be made for mechanical stops at the required actuators so that damage will not result from excessive commands. Stops where indicated shall be non-jamming.

### **3.10.2 Secondary Flight Control System**

**3.10.2.1 LIFT AND DRAG INCREASING SYSTEMS.** The Leading and Trailing Edge Flap System is depicted in Figure 3-32.

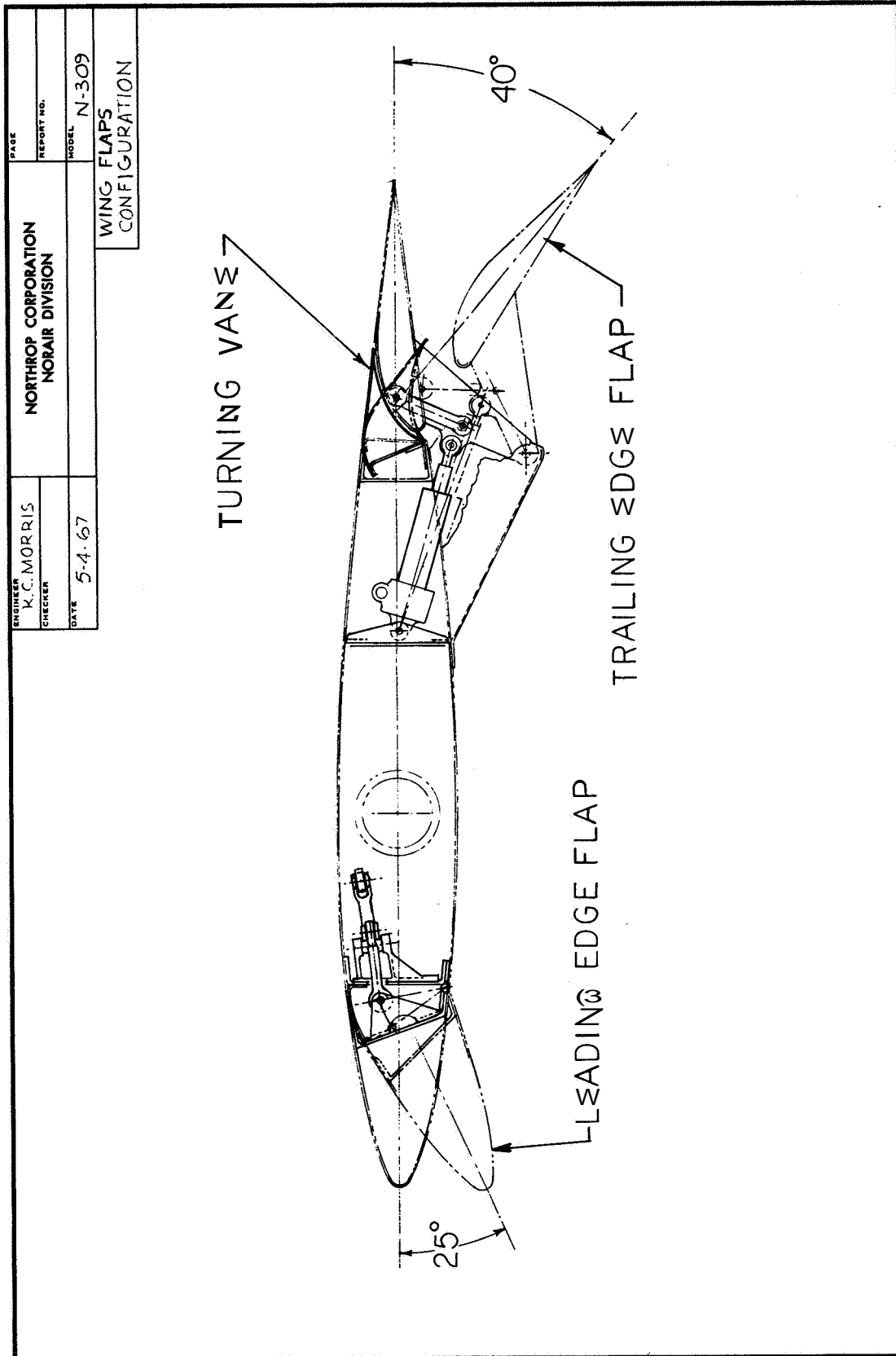


FIGURE 3-32

**3.10.2.1.1 Wing Flap Control System.** The wing flaps shall be operated electrically. The flaps shall be controlled by a three-position switch with "up" ( $0^{\circ}$ ), "down" ( $40^{\circ}$ ), and "approach" ( $25^{\circ}$ ) positions, adjacent to which shall be located a position indication display. Asymmetric flap deflections shall be prevented by a mechanical interconnect.

**3.10.2.1.2 Leading Edge Flap Control System.** The leading edge flaps shall be operated electrically. The flaps shall be programmed so that they are deflected any time the trailing edge flaps are deflected. Asymmetrical flap deflection shall be prevented by a mechanical interconnection. Maximum deflection is 25 degrees.

### **3.10.3 Stability Augmentation System**

The stability augmentation system is an integral part of the flight control system described in paragraph 3.10.1. The augmentation shall provide damping on all three airplane axes. Dual redundant actuators, sensors, power supply and electronic equipment shall be installed. Detailed specifications are contained in Appendix III.

## **3.11 ENGINE SECTIONS**

The engine sections shall consist of two nacelles and compartments in the center fuselage. See Drawing AD 4515 (Figure 3-33).

### **3.11.1 Description and Components**

The nacelle group shall consist of two engine nacelles, each containing a propulsion engine, diverter valve, longitudinal ducting, downward and inward ducting to lift nozzles in the fuselage and mounting space provisions for the engine driven gear boxes and for support and retraction of the main landing gear units. The center fuselage compartments shall contain the lift engines, mounted in vertical attitudes, with associated fuel lines and controls; also the ducting from the lift and propulsion engines to the nozzles described in 3.12.6.1. It shall incorporate doors in the upper and lower surfaces to permit air induction and exhaust during operation of the lift engines. The design shall provide for access to all servicing locations and interchangeability of engines and landing gear units.

### **3.11.2 Construction**

The engine section of the nacelle shall incorporate firewalls of fireproof material to isolate aircraft structure and equipment in accordance with the environ-

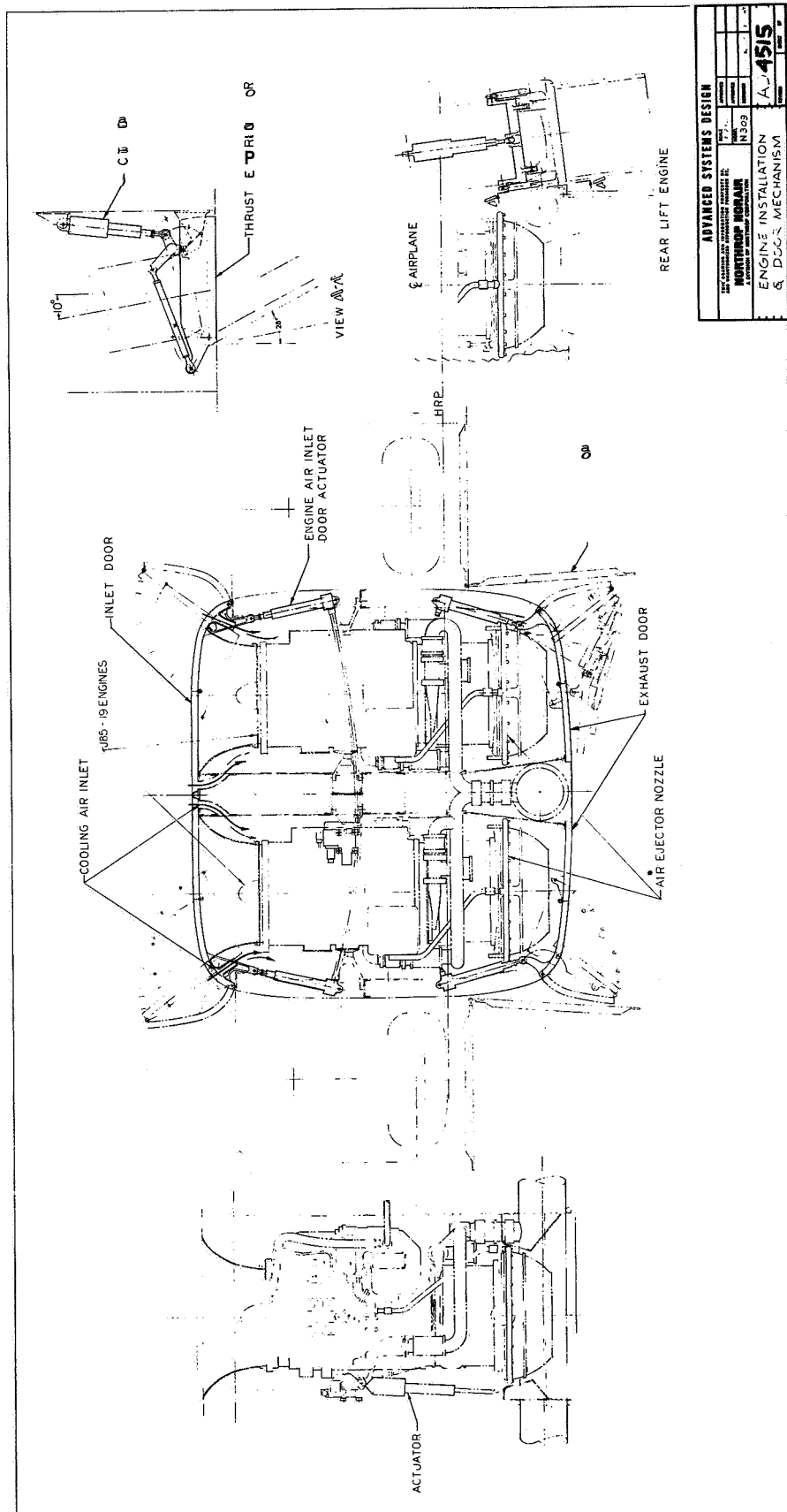


FIGURE 3-33

mental recommendations of the engine manufacturer. The seven or eight lift engines shall be isolated completely from each other and from adjacent fuselage and nacelle structure by firewalls of fireproof material which may serve as structural members for support of the lift engines and associated items. The remainder of the nacelles and center fuselage compartment shall be of aluminum alloy, or titanium alloy reinforced sheet metal construction as imposed by local temperature requirements.

#### 3.11.3 Engine Mounting

The engine mounts shall be of the trunnion and steady rest type in accordance with recommendations of the engine manufacturer. In general, the mounting brackets shall be rigidly attached to the fuselage and nacelle frames, with provision for absorbing changes in engine dimensions due to expansion and contraction.

#### 3.11.4 Vibration Isolation

Design of anti-vibration provisions, if required, shall be in accordance with the recommendations of the engine manufacturer.

### 3.12 PROPULSION

#### 3.12.1 Description

In the composite-lift configuration, propulsive power for vertical lift shall be provided by seven turbojet lift engines and two lift/cruise engines which also provide forward propulsion for conventional flight. In the direct-lift configuration, vertical lift shall be provided by eight lift-only engines and forward propulsion by two cruise engines.

The lift-only engines shall be vertically mounted, while the two used for both lift and forward propulsion in the composite lift configuration shall be horizontally mounted incorporating diverter valves for exhaust control when providing lift. With the diverter valves in the "lift" position, the two lift/cruise engine exhausts are directed inboard and downward through the fuselage near the aircraft centerline with the nozzles discharging at a rearward angle of 10 degrees to the vertical. The composite-lift configuration is illustrated in Figure 3-34.

In the direct-lift configuration, the aft, centerline, lift engine, diverter valves and associated tailpipes are removed. The diverter valves are replaced by sections of tailpipe to provide direct flow of exhaust to the cruise nozzles. The space made available by the removal of hardware in the aft engine bay is utilized to install two lift engines.

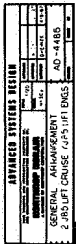


FIGURE 3-34

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Variable vectoring nozzles shall be installed on each lift engine. A combination closure and vectoring door shall be installed below the diverted exhaust exit of each lift/cruise engine.

### 3.12.2 Main Propulsion Units

General Electric YJ85-19 engines shall be used for the lift and lift/cruise applications. Performance guarantees and engine weights as specified in the General Electric Model Specification E1129 (dated 1 November 1966) shall apply.

#### 3.12.2.1 DATA FOR AIRCRAFT PERFORMANCE.

3.12.2.1.1 Basic Engine Performance. As indicated in the applicable engine specification, the rating of all the lift engines and the lift/cruise engines in the lift mode shall be 3,015 pounds maximum static uninstalled thrust at sea level, standard day conditions with zero bleed and accessory power extracted, with an exhaust nozzle sized for zero bleed. The rating shall be for five minutes duration. The cruise engines shall have a thrust rating of 2,950 pounds for thirty minutes duration.

3.12.2.1.2 Installed Performance. The exhaust areas of all lift engines and those of the lift/cruise engines in the lift mode shall be sized for constant maximum engine power operation at limit engine speed (98.97% rpm) and exhaust gas temperature ( $T_5 = 1779^\circ\text{R}$ ) while extracting maximum compressor bleed air ( $W_B/W_A = 0.10$ ) at the ambient test conditions of sea level and  $80^\circ\text{F}$ . The exhaust area of the cruise engine shall be sized to yield constant military power operation ( $N = 99.2\%$  RPM,  $T_{51} = 1765^\circ\text{R}$ ), with a bleed rate of one per cent and an accessory power extraction of thirty horsepower.

Installation thrust losses for the lift and lift/cruise engines for static operation at maximum engine speeds shall not exceed the following:

<u>Installation Losses. <math>\Delta F/F</math></u>			
	(1) $P_{t_2}/P_{t_o} = 0.995$	L/C Engine	
	(2) $P_{t_2}/P_{t_o} = 0.990$	Lift Engine	Lift Cruise
Inlet Press. Recovery	(1) 0.007	(2) 0.14	(2) 0.14
Vectoring Nozzle	0.015	-	-
Diverter and Tailpipe	-	0.033	0.025

Installed performances of the lift and lift/cruise engines in the lift mode shall be as depicted in Figures 3-35 and 3-36. Lift capability of the entire system, propulsion and control system, shall be as shown in Figures 3-37 and 3-38.

**3.12.2.1.3 VTOL Control Thrust.** System losses contributing to a loss of control thrust from the engine bleed air shall not exceed the following:

1. Line pressure loss from the compressor exit port to the control nozzle shall not exceed **15%**( $\Delta P/P = 0.15$ ) at maximum bleed rate and simultaneous control application and **20%**( $\Delta P/P = 0.20$ ) for **100%** control on any one individual axis.
2. System bleed air leakage shall not exceed **3%** of the control bleed air.
3. Control nozzle velocity coefficient shall not be less than **0.96** in the fully open position.
4. Control nozzle discharge coefficient shall not be less than **0.95** in the fully open position.

Bleed air quality and control thrust available per each lift and lift/cruise engine shall be as shown in Figures 3-39 and 3-40. These data include bleed air quantities not available for control purposes as system losses, i.e., 0.5% of compressor airflow for engine-bay cooling and, for the lift/cruise engines only, an additional 0.5% of compressor airflow for cockpit conditioning.

**3.12.2.1.4 Vectoring Nozzle Performance.** Single-plane spherical vectoring nozzles shall be attached to each lift engine. The nozzle itself shall have a vectoring capability of **28** degrees fore-and-aft of the engine centerline. Installation in the aircraft shall limit the forward travel to **15** degrees while aft travel remains unlimited to **28** degrees. In the unvectoring position, the thrust loss shall not exceed 1.5 percent of the basic YJ85-19 engine nozzle. No spherical vectoring nozzle will be installed on the lift/cruise engine. Instead, a vectoring door shall be installed below the lift exhaust nozzle of each lift/cruise engine which, in conjunction with the 10-degree aft canted angle of the nozzle, will provide an effective vectoring of **28** degrees. No forward vectoring is provided for the lift/cruise engine with this arrangement. The vectoring efficiency of the spherical nozzle and vectoring door shall be as shown in Figure 3-41.

**3.12.2.1.5 Hot Gas Ingestion.** The aircraft design shall shield the intakes of all engines from vertically rising engine exhaust gas to preclude hot gas ingestion in close ground proximity (landing gear height). Experience with full-scale test vehicles utilizing J85 engines indicated that the hot gas phenomenon in close ground proximity

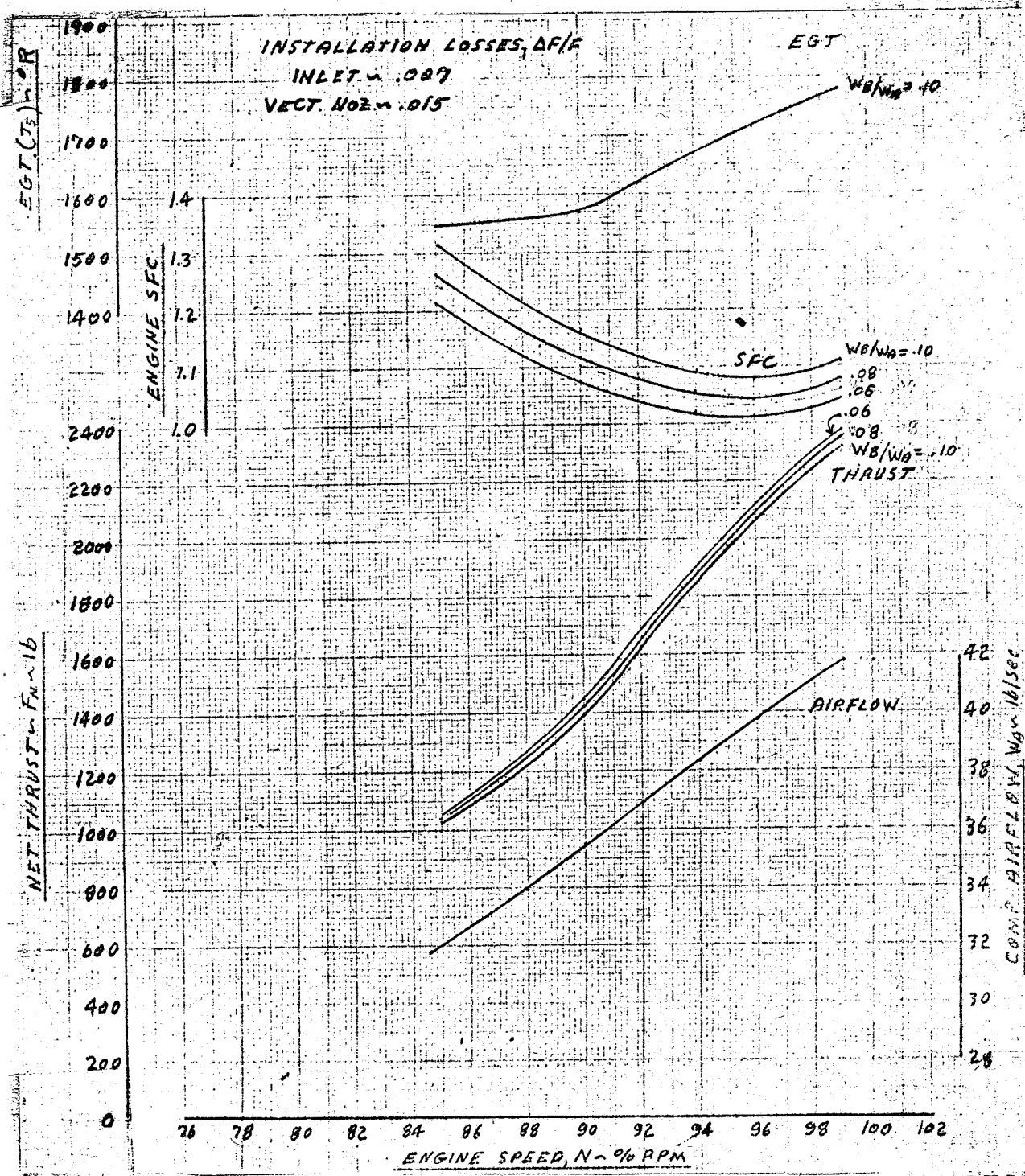


FIGURE 3-35. YJ85-19 LIFT ENGINE PERFORMANCE, INSTALLED,  
 SEA-LEVEL, 80°F, EXHAUST NOZZLE SIZED FOR CONSTANT 10% BLEED,  
 ( $A = 109.5 \text{ in.}^2$ )

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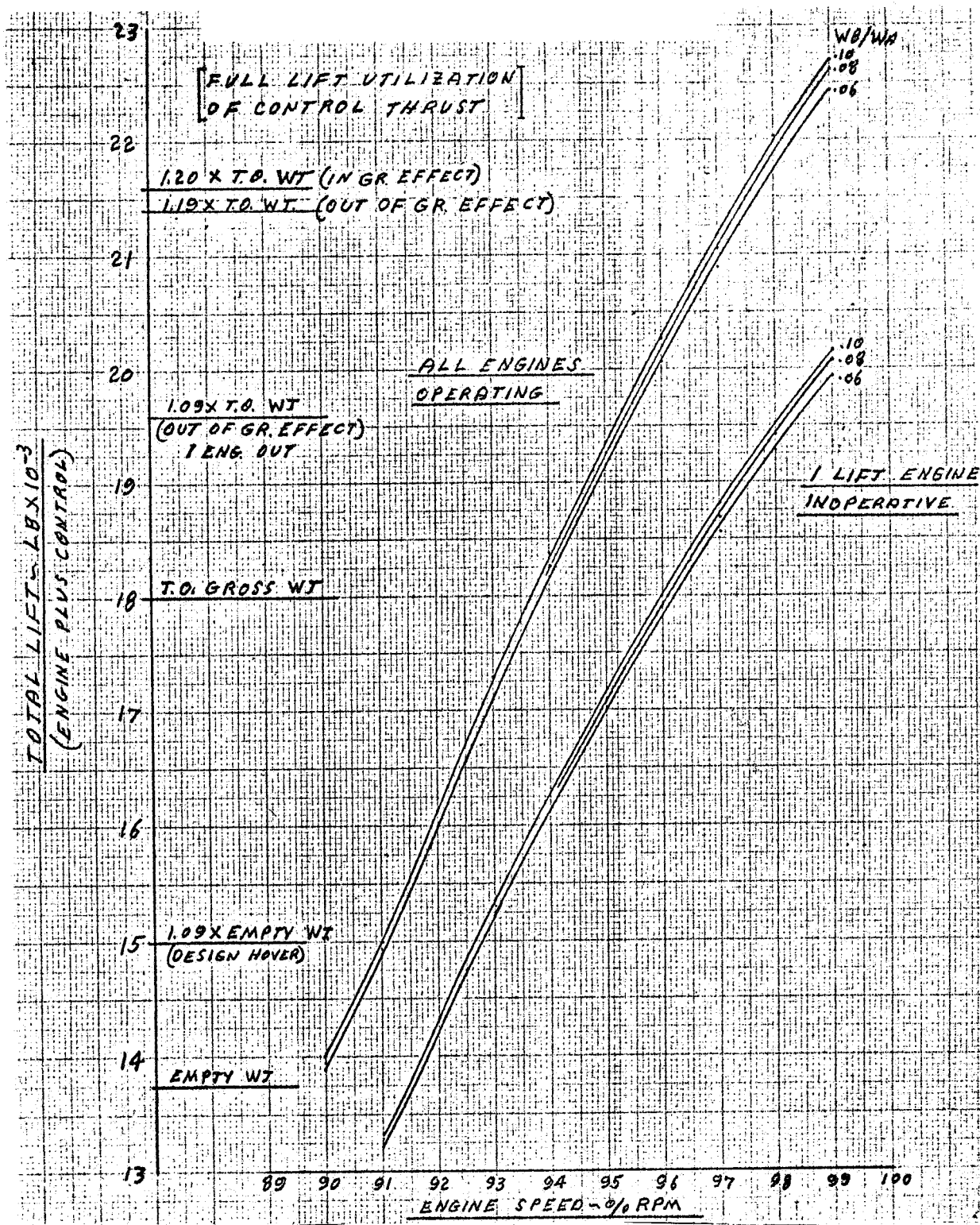


FIGURE 3-37. LIFT CAPABILITY, NEW AIRCRAFT, N-309 COMPOSITE LIFT MODE, 7 LIFT, 2 L/C YJ85-19 ENGINES, SEA-LEVEL, 80°F

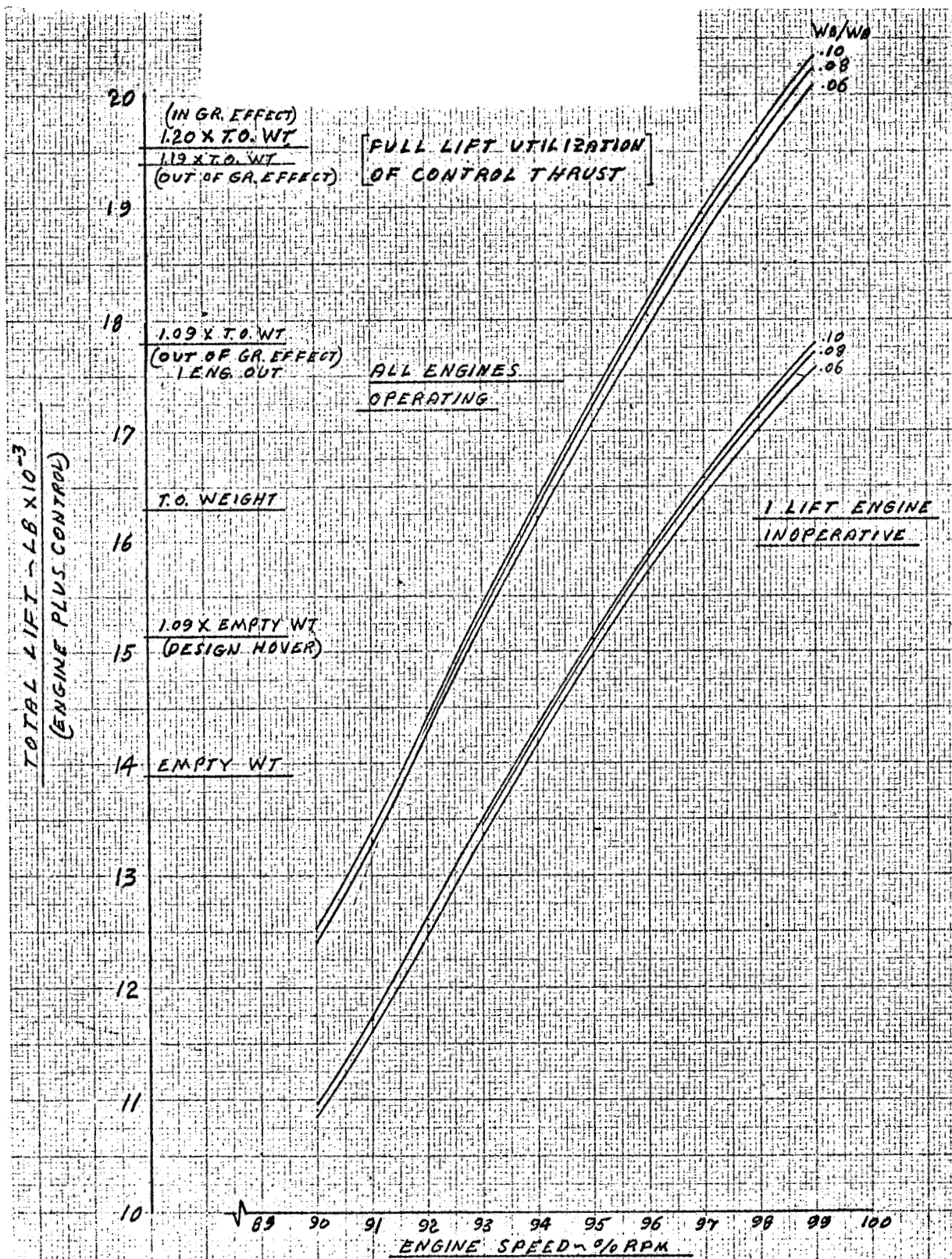


FIGURE 3-38. LIFT CAPABILITY, NEW AIRCRAFT, N-309  
DIRECT LIFT MODE, 8 LIFT YJ85-19 ENGINES, SEA LEVEL, 80°F

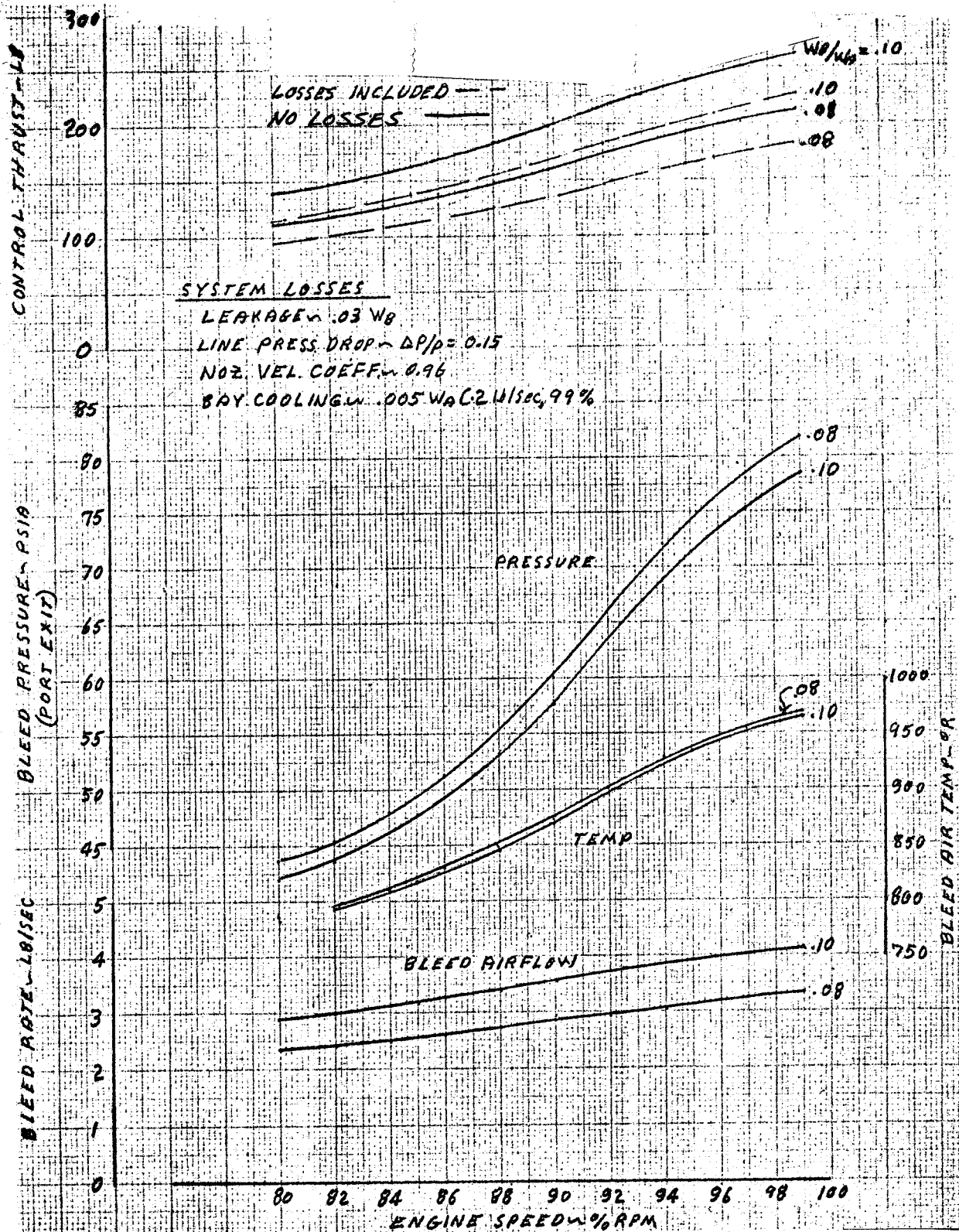


FIGURE 3-39. YJ85-19 LIFT ENGINE PERFORMANCE BLEED AIR QUALITY AND CONTROL, THRUST INSTALLED, SEA-LEVEL, 80°F, EXHAUST NOZZLE SIZED FOR CONSTANT 10% BLEED ( $A_g = 109.5$ )

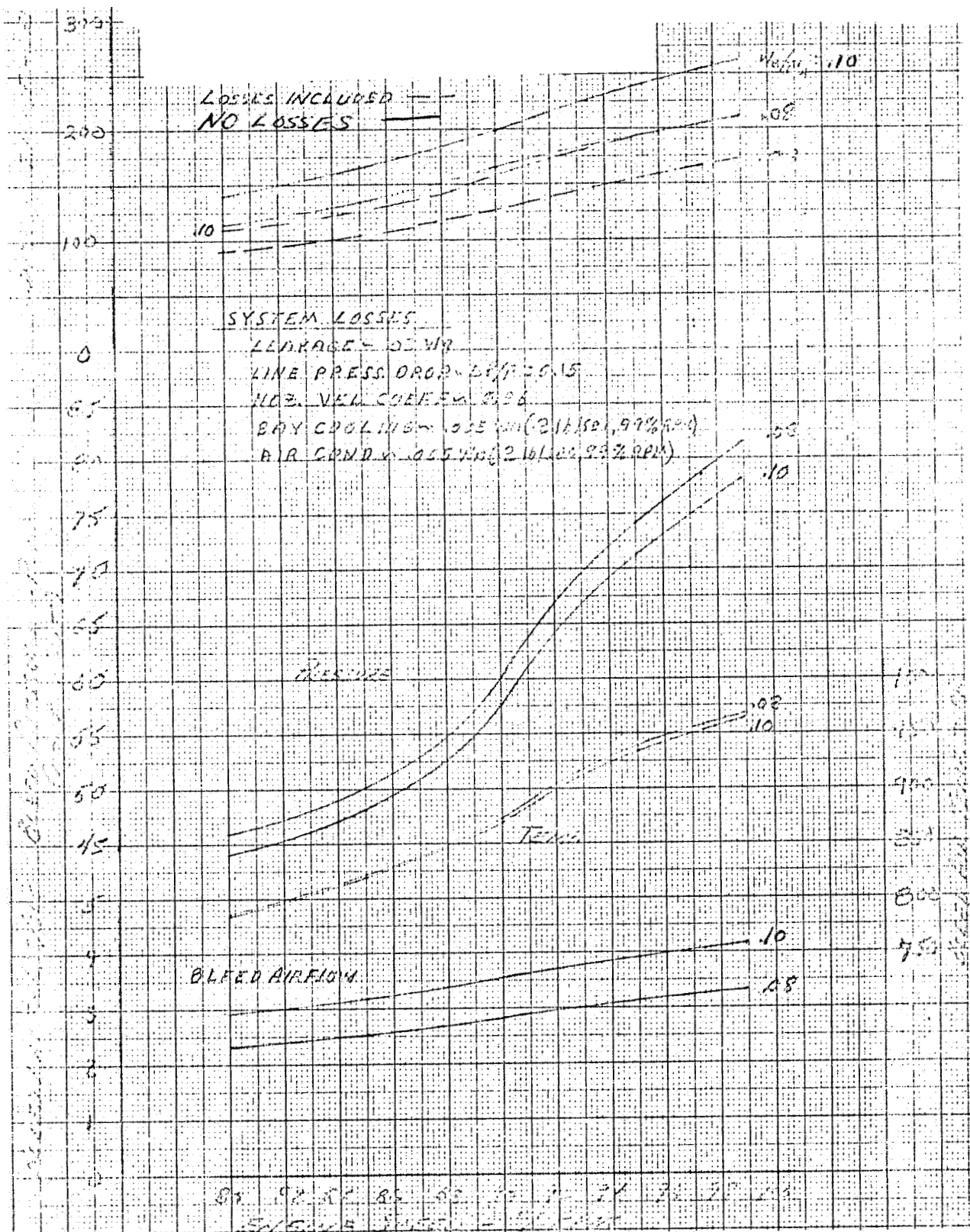


FIGURE 3-40. J85-19 L/C ENGINE PERFORMANCE - BLEED AIR QUALITY AND CONTROL THRUST - INSTALLED, SEA LEVEL, 80°F DAY, EXHAUST NOZZLE SIZED FOR CONSTANT 10% BLEED, ( $A_g = 114.46$ )

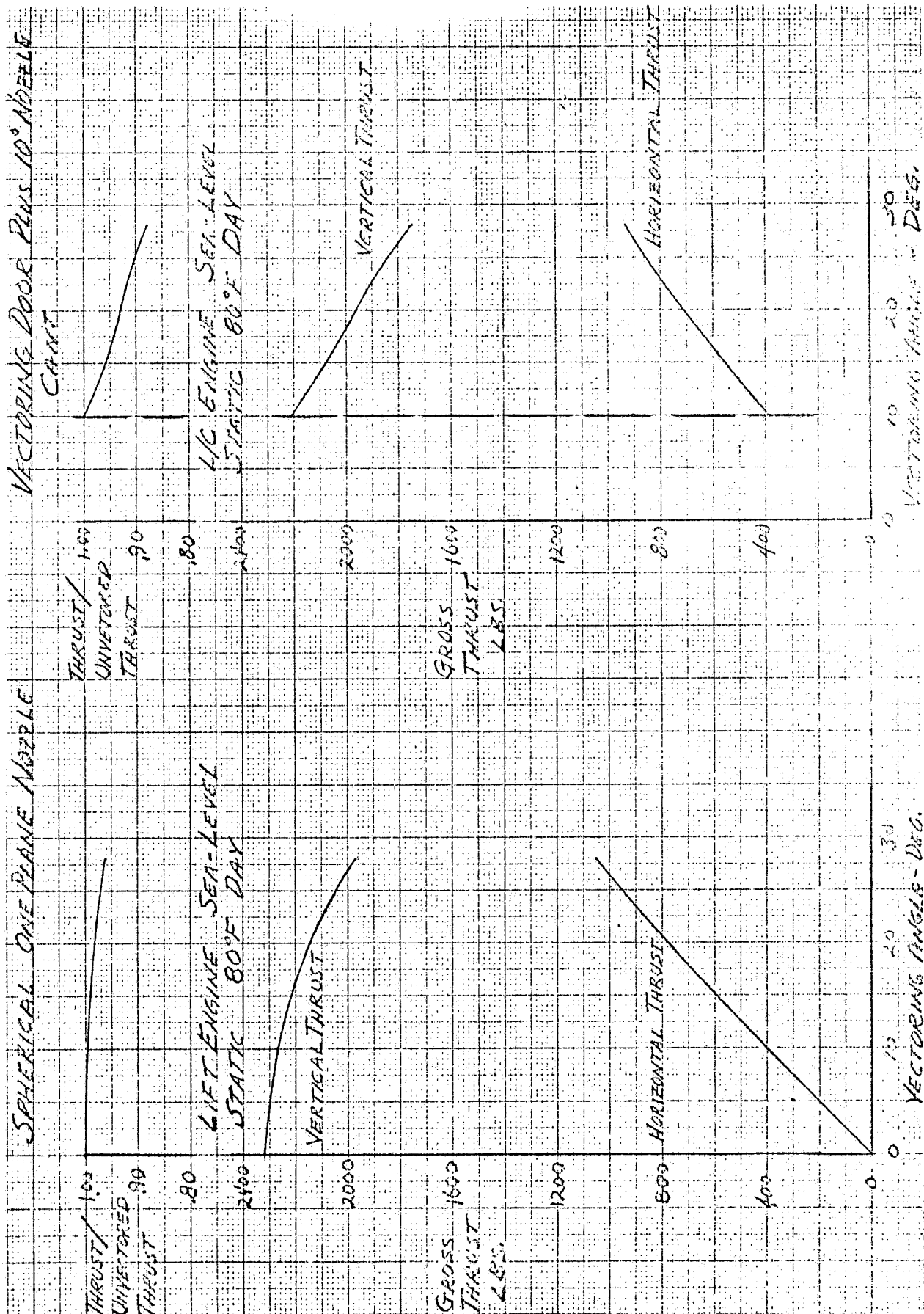


FIGURE 3-41. PROPULSION THRUST VECTORING EFFICIENCY, NEW A/C

is random by nature and highly dependent on the configuration, particularly on engine spacing and location of the wing relative to the intakes. Gas ingestion, when it occurs near the ground, can result in high temperature distortion at the engine compressor face sufficient to cause compressor stalls, even though the overall temperature rise may be small. In the N-309 design, the low wing location provides protection to the intakes of the lift/cruise engines and all lift engines except the forward pair. In this area, the closure doors, which are longitudinally hinged and swing out nearly horizontally with the lower fuselage surface, force any hot gas outward from the fuselage, prohibiting the attachment of hot gases to the sides of the fuselage.

### 3.12.3 Auxiliary Propulsion Unit

None provided.

### 3.12.4 Engine Driven Accessories

Only the engines used for forward propulsion shall incorporate provisions for driving accessories other than those required for the operation of the engine.

3.12.4.1 DESCRIPTION AND COMPONENTS. Engine driven accessories shall include a fuselage mounted gearbox driving a variable volume hydraulic pump and a constant speed three phase alternator. An additional hydraulic pump shall be mounted on each engine.

### 3.12.5 Air Induction System

3.12.5.1 LIFT ENGINES. The air induction system for the vertical lift engines shall consist of nearly circular openings having bell-mouth type boundaries. Devices to improve performance of the basic bell mouth will be incorporated into the design to provide satisfactory inlet recovery and distortion during transitional flight and, particularly, during the engine start and acceleration phases prior to transition to hover flight. The inlets shall be equipped with power actuated closure doors, operated by mode selector switch, designed to prevent door closing with any of the lift engines in operation. The door actuators shall remain in the selected position in the event of a hydraulic or electrical system failure.

3.12.5.2 LIFT/CRUISE ENGINES. The inlets of the forward propulsion engines shall be fixed and designed for operation throughout the entire speed range.

3.12.5.3 ICE PROTECTION SYSTEM. No ice protection shall be furnished.

### 3.12.6 Exhaust System

3.12.6.1 DESCRIPTION AND COMPONENTS. The exhaust system shall consist of tailpipes and rotating, convergent nozzles for the vertical lift engines, and the diverter valves, tailpipes and fixed nozzles for the two horizontal engines. . The tailpipes ~~for~~ all lift engines shall be constructed of high temperature-resistant material. The exhaust openings ~~of~~ the lift engines shall be equipped with longitudinally-hinged closure doors, hinged along the outside edge and opening in a downward and outward direction. The door actuators shall remain in the selected position in the event of a hydraulic or electrical system failure, The exhaust tailpipe ducting for the lifting mode of the lift/cruise engines shall be attached to the diverter valve and direct the exhaust into and downward through the fuselage close to the airplane centerline to minimize roll moments in case ~~of~~ engine failure. A convergent propulsion nozzle shall be affixed to this tailpipe discharging at a rearward angle of ten degrees to the vertical. A combination vectoring and closure door shall provide an effective aft vectoring angle ~~of~~ twenty-eight degrees.

3.12.6.1.2 Vectoring Nozzles. General Electric, single-plane-of-rotation, spherical, vectoring, convergent nozzles that are under development shall be attached to each lift engine exhaust system. These hydraulically driven nozzles shall have an angular motion parallel to the plane of symmetry ~~of~~  $\pm 28^{\circ}$  from the neutral setting. Actuation of the pilot's control shall position an electro-mechanical actuator which in turn drives the nozzle hydraulic power actuators. The nozzles shall be designed and positioned to minimize lift interface effects.

3.12.6.1.3 Diverter Valves. General Electric diverter valves equivalent to their X 353-5B system diverter valves shall be attached to the turbine exit flanges of the lift/cruise engines according to the engine manufacturers recommendations.

### 3.12.7 Cooling System

3.12.7.1 DESCRIPTION AND COMPONENTS. Ejector pumps utilizing compressor bleed air shall be used to cool each engine bay during both ground and flight operation. The system shall consist of a circular distribution tube located above the rotatable

nozzles with twenty equally spaced ejector nozzles sized to flow 0.5% of compressor airflow at maximum engine speed. Cooling air shall be admitted through cutouts in the upper fuselage surface outside of the bell mouth proper to preclude the possibility of direct hot gas ingestion. Cooling air for the cruise engine bays shall originate through cutouts in the inlet surface with the ejector pump operable during both hover and conventional flight.

### **3.12.8 Lubricating System**

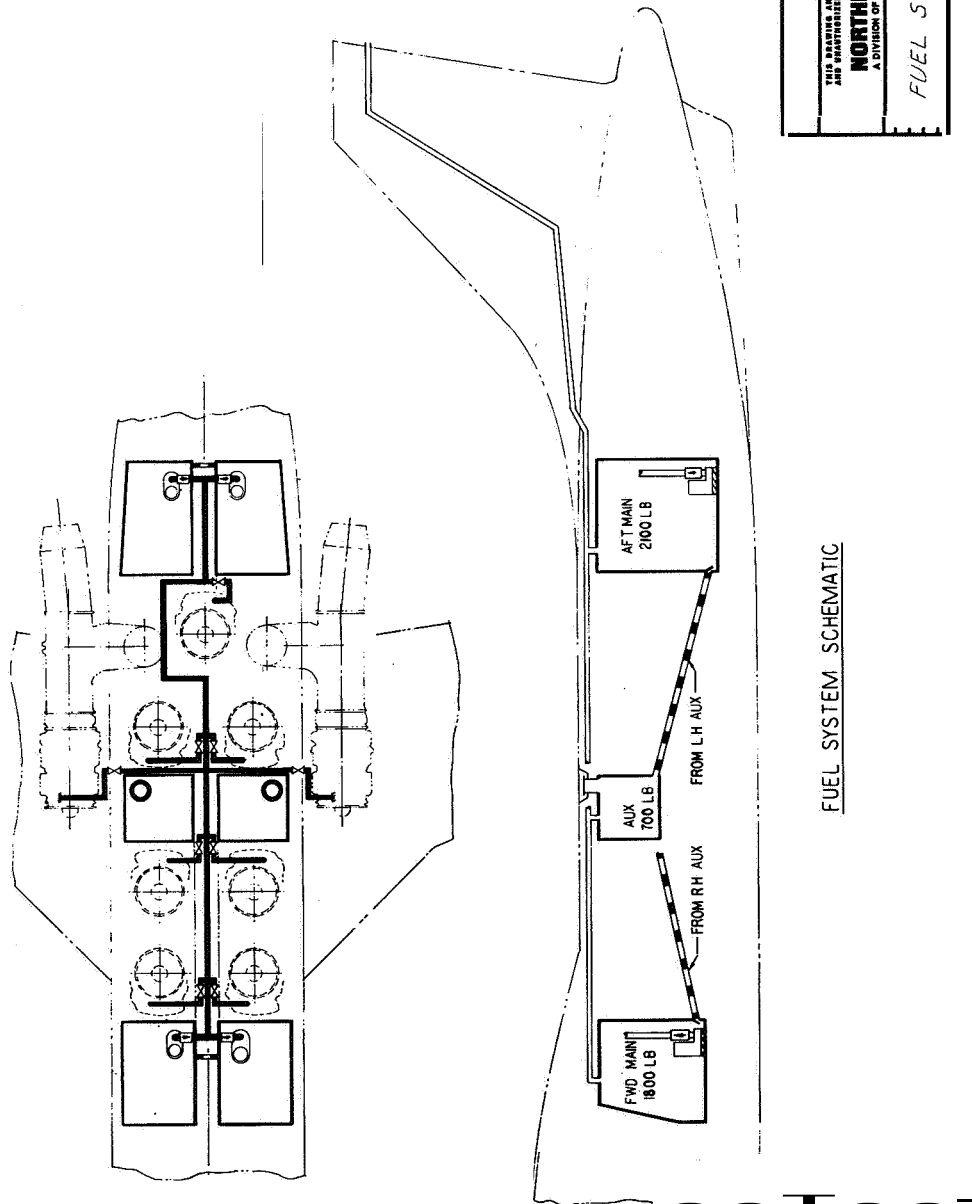
**3.12.8.1 DESCRIPTION AND COMPONENTS.** Each engine and accessory drive unit shall incorporate an integral lubrication system furnished by the manufacturer, including provisions for oil storage and cooling, where required. Convenient access doors shall be supplied for servicing the systems.

**3.12.8.2 OIL INDICATING SYSTEM.** An oil pressure gage shall be provided on both instrument panels for each horizontal engine, and a low pressure warning light for each vertical engine on the cockpit enunciator panel.

### **3.12.9 Fuel System**

The fuel system schematic is shown in Figure 3-42 (Drawing AD 4519). Indicated are the capacities of the two forward and two aft main tanks and the two auxiliary tanks,.

**3.12.9.1 FUEL TANKS.** The normal fuel load of **4300** pounds of which **300** pounds is used for engine start and pre-flight warmup, is carried in six bladder cells, arranged in three LH and RH pairs of fuselage tanks. The center pair, auxiliary tanks, drain by gravity into the forward and aft pairs of main tanks which hold a majority of the fuel. An additional 300 pounds may be carried in the aft main tanks for STOL missions or additional warmup fuel. Each pair of main tanks is interconnected to provide added reliability, and inverted flight capability can be easily provided for inadvertent emergency operation. Four boost pumps, one in each main tank, supply fuel to all engines, but any three pumps can supply critical hover fuel flows. In case of a single boost pump failure, a cockpit warning light would advise the pilot, so that in conventional flight, he may turn off one of the two pumps in the opposite pair of main tanks before excessive CG shift is encountered. Inasmuch as engine specifications require operation with aircraft boost pumps inoperative at altitude conditions more stringent than



FUEL SYSTEM SCHEMATIC

ADVANCED SYSTEMS DESIGN			
THIS DRAWING AND INFORMATION PROPERTY OF: <b>NORTHROP NORAIR</b> A DIVISION OF NORTHROP CORPORATION	SCALE AS SHOWN	APPROVED DESIGNER C. R. RICH	DATE 5-23-72
FUEL SYSTEM SCHEMATIC		AD 4519	

FIGURE 3-42

those expected in hover operation of this aircraft, a pump failure, or even complete electrical failure could be experienced without causing a critical landing emergency. Two gravity fillers, one in each auxiliary tank, provide for complete fueling of the airplane through the tank interconnects. All tanks are vented to a single, open vent line exhausting from the vertical stabilizer.

### **3.12.10 Propulsion System Controls**

**3.12.10.1 DESCRIPTION AND COMPONENTS.** The propulsion system controls shall consist of power level controls for the horizontal and vertical engines and the starting controls. The latter consists of switches electrically sequenced for single pushbutton start.

**3.12.10.2 ENGINE THRUST CONTROLS.** The engine thrust control system shall consist of one conventional throttle control lever for the two cruise engines and one conventional throttle control lever for the lift engines in a side-by-side arrangement. Thrust level control shall be by means of electric closed-loop servos from the front, or evaluation pilot's cockpit and manually with parallel power boost from the back cockpit to the electric actuators controlling the power lever on each engine. This arrangement shall be compatible with the requirements for the **VSS**, and for additional information see Appendix III.

### **3.12.11 Starting System**

A diagram of the engine starting system is depicted in Figure 4-43 (Drawing AD 4514).

**3.12.11.1 DESCRIPTION AND COMPONENTS.** All engines shall be started by impingement of compressed air on the turbine blades, through the bleed manifold system. All engines shall be ground started using an external source of compressed air. The vertical engines can also be started by using bleed air from the horizontal engines. Individual lines from the bleed manifold to each starting connection shall incorporate valves controllable from the cockpit start switches and automatic sequencing. An external connection to the bleed manifold shall be provided for use of an external starter cart.



### 3.12.12 Nacelle Preheating System

No provisions shall be made for preheating the engine accessories or components of the fuel and oil systems.

### 3.12.13 Auxiliary Power Unit

No provisions shall be made for the installation of an APU.

### 3.12.14 Compressor Bleed System

A compressor bleed system shall be installed for the purposes of supplying compressed air to the reaction controls, the air conditioning system and the impingement starting system. Compressor bleed air shall be extracted from each engine and ducted to a central manifold. Ducts shall extend from this manifold to the reaction control nozzles at the fuselage extremities and wing tips; to the impingement starting connections on each lift engine; and to the air conditioning unit. Each line supplying the manifold shall incorporate a controllable shut-off valve. All ducts will incorporate bellows as required to relieve loads due to heat expansion or airframe deflections. The reaction control nozzles shall be designed to supply thrust on a semi-continuous bleed basis. The bleed manifold and ducts shall be of thin wall corrosion resistant alloy, with insulation where required for structural, equipment, or personnel protection. Refer to Drawing AD 4499, Figure 3-44.

**3.12.14.1 REACTION JET NOZZLES.** The reaction jet nozzles shall be designed to minimize engine bleed losses. The fore and aft nozzles shall exhaust downward and modulate thrust differentially for pitch control and rotate appositely for yaw control, When rotated beyond  $40^{\circ}$ , nozzle areas shall increase from 18.3 to 20.8 square inches to limit rotation to  $54^{\circ}$  retaining sufficiently small pitch/yaw nozzle "null" areas so that full roll moment is possible. The roll control nozzles shall exhaust downward and modulate thrust differentially except for extreme demands when the exhaust is down at one wing tip and up at the other. The roll nozzle "null" areas shall be sized to allow full pitch control with no change in roll nozzle area. Each roll nozzle shall be scheduled to open from 5.0 to 7.2 square inches after the opposite one closes and before the opposite one discharges up. Fifty percent of maximum roll moment shall thus be attained with minimum cross coupling. Ratio changers in the control mechanization of the pitch/yaw and roll control nozzles shall close the nozzles to the zero opening position during cruise flight.

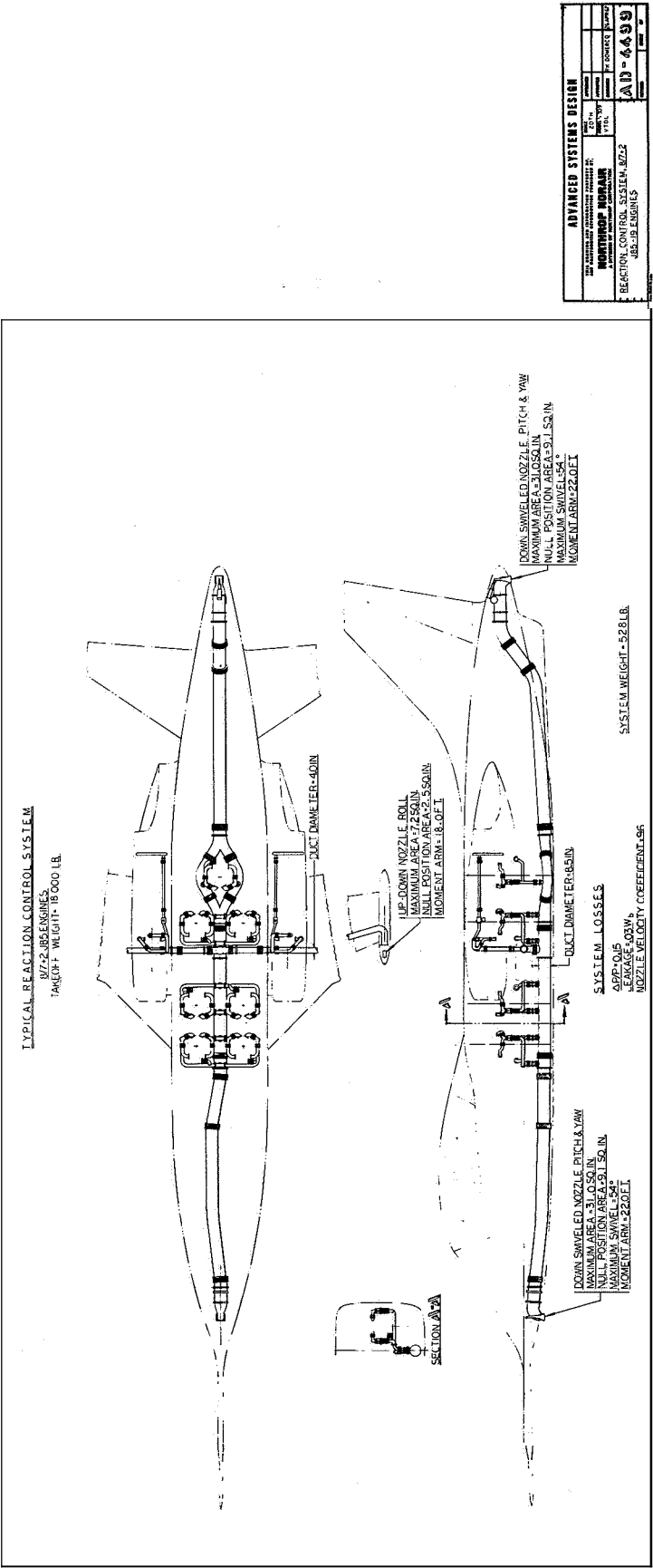


FIGURE 3-44

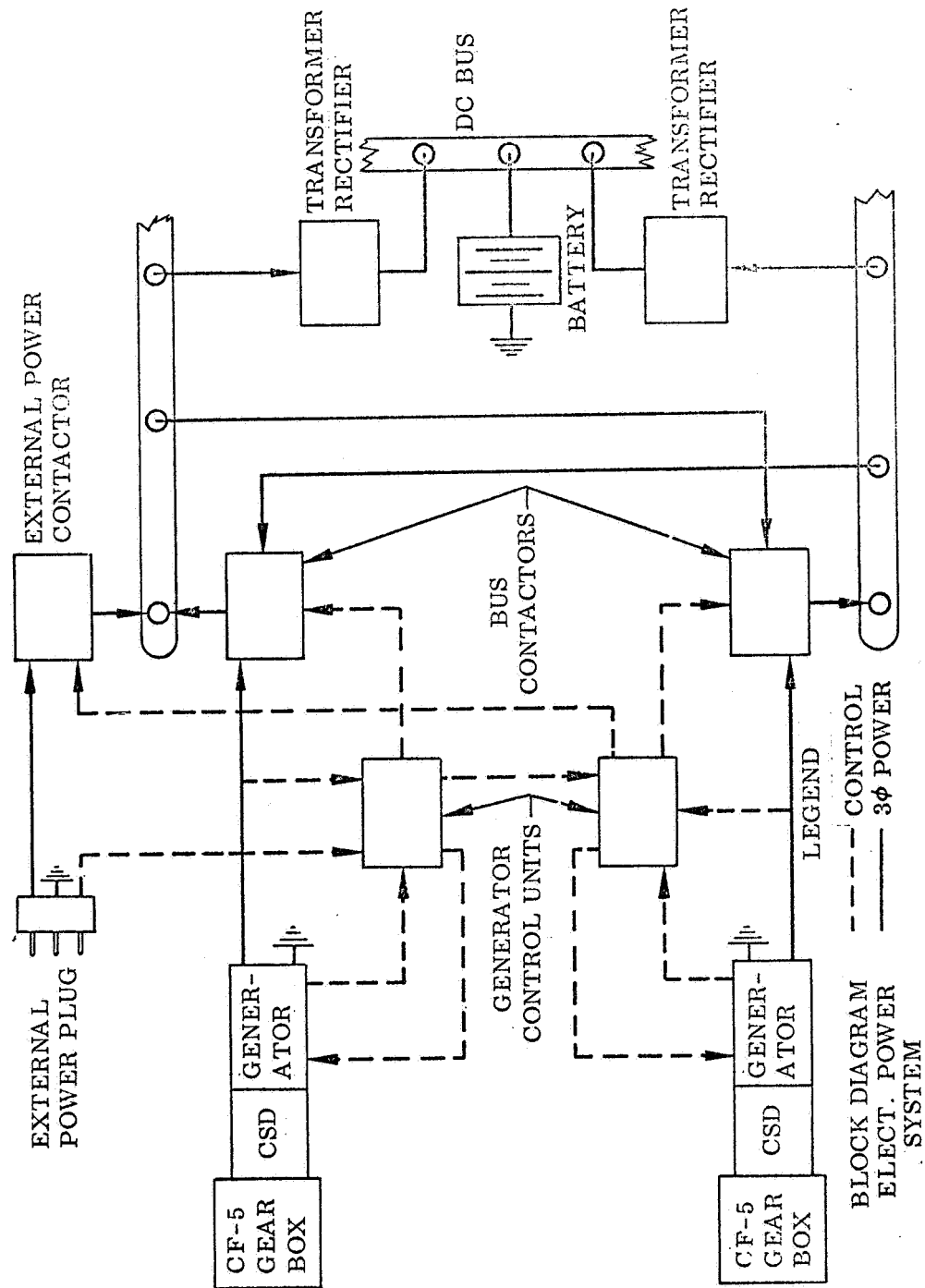


FIGURE 3-45. BLOCK DIAGRAM - ELECTRICAL POWER SYSTEM

### 3.13 SECONDARY POWER AND DISTRIBUTION SYSTEM

#### 3.13.1 Electrical Power and Distribution Subsystems

3.13.1.1 ELECTRICAL SYSTEM. The primary electrical system shall consist of two 15 KVA three phase alternating current generators as the power source. Secondary DC power is furnished by two transformer-rectifiers energized by the AC generators. A schematic diagram is **shown** in Figure 3-45, Block Diagram - Electrical Power System.

3.13.1.2 ELECTRICAL POWER SUPPLY. The two AC generators shall be driven by the cruise engines through fuselage mounted gear boxes incorporating constant speed drive. The AC power distribution system shall consist **of** two isolated systems, each supplying its own load. Automatic bus switching shall occur in the event of a generator failure.

3.13.1.2.1 Wiring. The electric wiring installation shall be generally in accordance with the requirements of Specification MIL-W-5088. The installation of any electrical wire or cable that is subject to flexing during operations or use shall be in general accordance with Specification MIL-C-5756A.

3.13.1.2.2 DC Power Distribution. The DC outputs of the two transformer-rectifiers shall be connected to a main bus.

3.13.1.3 POWER SYSTEMS CONTROL. Switches shall be provided for each electrical system to select generator, OFF **or** external power. Advisory lights shall indicate generator OFF and be located on the annunciator panel.

#### 3.13.2 Hydraulic Subsystem

3.13.2.1 DESCRIPTION AND COMPONENTS. A hydraulic system using MIL-H-5606 fluid shall be provided. The system, shown schematically in Drawing AD 4496, Figure 3-46, shall be composed of two functionally independent systems. Design and installation of the systems shall be in general accordance with MIL-H-5440C, Type II. Normal operating pressure shall be 3000 psi. Each system shall be supplied by a fuselage mounted gear box and an engine-driven, variable volume pump. The LH

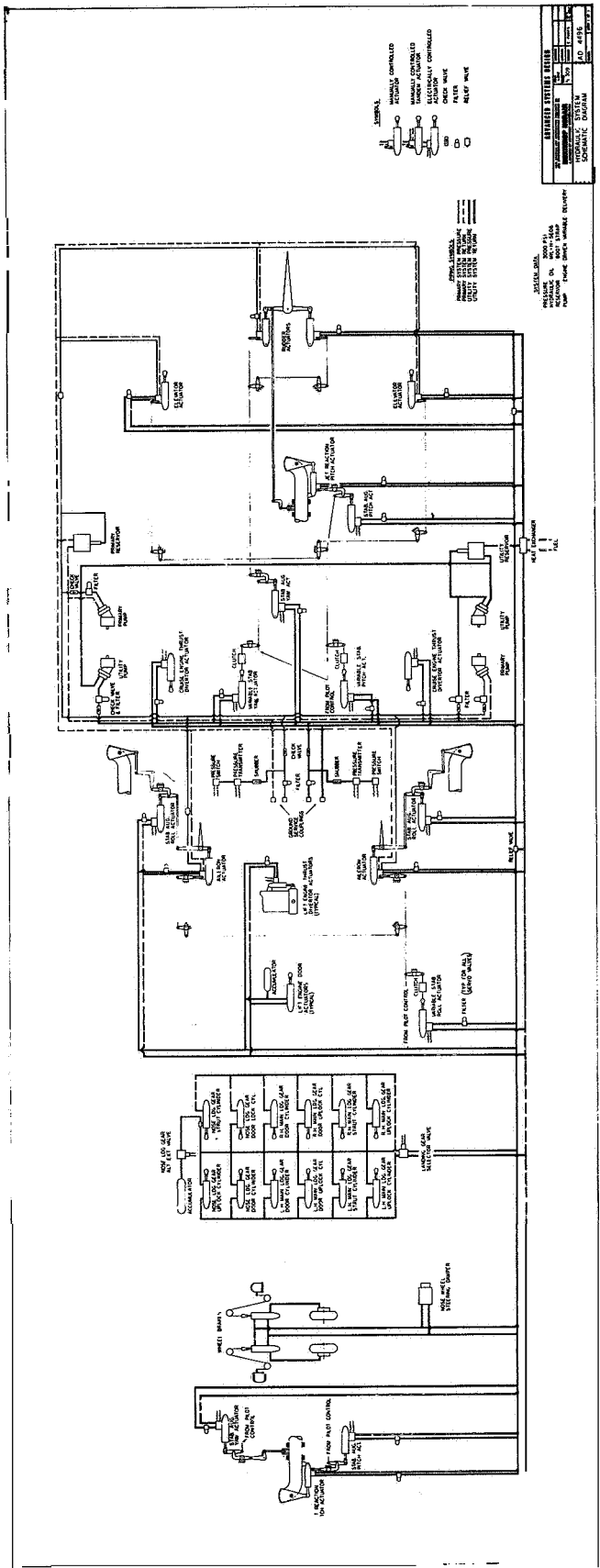


FIGURE 3-46

cruise engine driven gear box pump and the RH engine driven pump shall provide power for one system and the opposite combination shall provide the other. There shall be no interconnect between systems. Ground test connections shall be provided for use with Air Force standard portable, hydraulic system test stands. Flexible hose, when located in designated fire zones, shall be of approved fire-resistant type.

3.13.2.2 FLIGHT CONTROL AND UTILITY SYSTEMS. One of the above systems will be restricted to power only the primary flight control functions; the other (utility) system will power all other functions and also provide one half the control power to the primary flight controls. Under emergency conditions with either cruise engine or gear box inoperative, the remaining system(s) will provide adequate power for continuing flight and landing.

3.13.2.2.1 Landing Gear Emergency Actuation. Emergency extension of the main and nose landing gear shall be accomplished by gravity aided stored energy as required.

3.13.2.2.2 Wheel Brakes. The wheel brakes shall be of the power-boost type. Under emergency when the utility hydraulic system is inoperative, the wheel brake system shall revert to a manual pressure generating type. Parking brakes shall be provided.

### 3.13.3 Pneumatic Subsystems

No pneumatic subsystem other than the compressor bleed system shall be installed.

## 3.14 UTILITIES AND EQUIPMENT ITEMS

### 3.14.1 Air Conditioning and Anti-Icing Equipment

3.14.1.1 AIR CONDITIONING. An air conditioning system shall be installed with a heating capacity sufficient to maintain 65° F in the crew compartment at 0° F OAT at pressure altitudes up to 25,000 feet at normal rated engine power. The system shall have a cooling capacity sufficient to maintain 85° F in the crew compartment at an OAT of 110° F when one thrust engine is at 86 percent RPM or higher. When the airplane is on the ground with engines inoperative, compressed air from an MA-1A Start Cart may be used. Crew compartment air temperature shall be manually

controlled by the crew. Ram air shall be provided for ventilation when required. Pressurization shall not be provided except that incidental to the air conditioning.

#### **3.14.1.2 ANTI-ICING.**

**3.14.1.2.1 Anti-Icing of Nontransparent Areas.** No provision shall be made for the anti-icing or de-icing of nontransparent areas.

**3.14.1.2.2 Defogging of Transparent Areas.** A defogging system shall be provided for the windshield panels. The defogging air will come from the cabin air supply line with no provisions for automatic control.

**3.14.1.3 WINDSHIELD RAIN REMOVAL.** No provisions shall be made for windshield rain removal.

#### **3.14.2 Fire Detection and Extinguishing Systems**

Fire detection equipment and indication in each cockpit shall be provided in accordance with Specification MIL-D-7006A. Fire extinguishing equipment shall not be provided.

#### **3.14.3 Instrumentation and Recording System**

Provision of on-board instrumentation and recording equipment shall be the responsibility of NASA except during contractor justification testing prior to aircraft delivery. As a **minimum**, VSS sensor signals will be compatible with NASA specified recording equipment requirements.

### **3.15 MISSION AND TRAFFIC CONTROL SUBSYSTEMS**

#### **3.15.1 Instruments**

**3.15.1.1 FLIGHT INSTRUMENTS.** The following flight instruments shall be installed for use by the crew,

- 2 - Air Speed/Mach Meter
- 2 - Clock (Elapsed Time)
- 2 - Vertical Velocity Indicators
- 2 - Pressure Altimeter Indicators
- 2 - Turn Slip, Side Slip and Lateral Velocity Indicators

- 2 - Attitude Indicators
- 3 - Bearing Indicators
- 2 - Angle of Attack Indicators
- 2 - **Radar** Altimeters
- 2 - Standby Compasses
- 1 - Accelerometer

**3.15.1.2 ENGINE INSTRUMENTS.** The following engine instruments shall be installed for use by the crew.

- 4 - Oil Pressure Indicator (~~Lift/Cruise~~ Engines)
- 1 - Fuel Management Indicator
- 3 - Multiple Tachometer - Indicators
- 3 - Multiple Exhaust Gas Temp. Indicators
- 4 - Multiple Thrust Indicators
- 1 - Fuel Quantity Indicator
- 1 - Fuel Balance Indicator
- 16 - Lift Engine Start Lights
- 16 - Lift Engine Fire Warning Lights

**3.15.1.3 MISCELLANEOUS INSTRUMENTS.** The following miscellaneous instruments shall be installed for use by the crew.

- 4 - Hydraulic Pressure Indicators
- 2 - Duct Pressure Indicators
- 2 - Flap Position Indicators
- 2 - Thrust Vector Indicators
- 2 - Take-Off Trim Indicators
- 2 - Nose Gear Strut Pressure Indicators
- 2 - Main Gear Strut Pressure Indicators (L. and R.)
- 2 - **Gear** Position Indicators

**3.15.1.3.1 Installation.** The instrument panel shall be arranged as **shown** on the cockpit arrangement drawings and comply, in general, with HIAD except that the engine instruments are displayed on the left side of the instrument panel **for** closer proximity to the throttles and more rapid monitoring. Space provisions only shall be provided for a Heads-Up-Display (HUD) for the evaluation pilot as indicated in the cockpit drawing, Figure 3-11. A portion of the instrument panel shall be replaceable for an advanced pictorial display, also shown in Figure 3-11.

### 3.15.2 Electronics

Space, weight and installation provisions shall be made in the fuselage for the electronic equipment listed in 3.15.2.1. This equipment, including installation components, shall be included in Weight Empty. Any additional equipment installed at the request of the procuring agency shall be considered as Useful Load.

3.15.2.1 INSTALLATION OF ELECTRONIC EQUIPMENT. The electronic equipment installed in the **aircraft** shall include the following:

(a) VORTAC	AN/RNA-26C NAC. REL. DMA-29L-DME Antennas
(b) IFF/SIF	AN/APX-72 Transponder Antennas
(c) ILS	MKA-28 Marker Beacon Antennas
(d) VHF	RTA-41B Transceiver
(e) Intercom	Microphone Amplifiers Headset
(f) Compass System	Gyro Stabilized Stable Platform Heading Coupler Controllers

3.15.2.2 ANTENNAS. Suitable antennas for the system listed in 3.15.2.1 shall be installed by the contractor.

### 3.16 MISSION SUBSYSTEMS

#### 3.16.1 Accommodations For Crew

3.16.1.1 SEATS. A North American LW-2D escape system shall be provided for each crew member. It is a rocket catapult powered ejection seat, fully automatic, two mode system with zero speed to 650 KEAS escape capability. The mode is selected at the time of ejection by a speed sensor at speeds greater than 200 knots and/or at altitudes over 10,000 feet. The stabilizing drogue parachute is ballistically

deployed as the seat leaves the aircraft so that it provides immediate seat stability after seat-aircraft separation. This drogue is separated from the seat at time of seat-man separation and provides forceful deployment of the personnel parachute. In the low speed low altitude mode, the personnel parachute is ballistically deployed as the seat clears the aircraft. In both the low and high speed mode, seat-man separation is effected by inflation of the personnel parachute which is mounted on the left-hand side of the seat back. This provides a built-in, lateral, rocket-thrust moment arm so that the man is always moving up and to the left of his deploying parachute. Therefore, left and right hand seats would be used to give lateral separation between seat trajectories and will be an additional safety factor. Egress from a disabled aircraft shall be through the canopy to minimize the ejection time cycle. Emergency provisions over, or on water is also provided with this escape system. A 20-pound survival kit is included in the ejectable weight.

3.16.1.2 AIRPLANE FLIGHT REPORT HOLDER. A flight report holder shall be installed in the aircraft.

3.16.1.3 MAP CASE. A map case shall be provided.

3.16.1.4 AIRPLANE DATA CASE. An airplane data case shall be provided.

3.16.1.5 AIRPLANE CHECK LIST HOLDER. A check list holder shall be installed at the pilot's station.

### 3.16.2 Furnishings

3.16.2.1 INSULATION, Insulation for protection against heat shall be installed adjacent to the engine exhaust ducts and bleed ducts as required to protect the adjacent structure and components and to prevent discomfort to the crew. The crew shall be protected against noise in general accordance with the applicable criteria of MIL-A-8806.

### 3.16.3 Oxygen Equipment

A gaseous oxygen storage and supply system shall be installed for the use of both crew members. The equipment shall supply, as a minimum, sufficient oxygen

for both crewmen on 100 percent oxygen for one hour. Quantity indicators and controls shall be located in each cockpit.

### **3.17 ARMAMENT**

Not applicable to the intended mission.

#### **3.17.1 Armament Control System**

Not applicable to the intended mission.

#### **3.17.2 Passive Defense**

Not applicable to the intended mission.

### **3.18 GROUND HANDLING AND SERVICING PROVISIONS**

#### **3.18.1 Towing Provisions**

Provisions for towing from the nose landing gear shall be made.

#### **3.18.2 Jacking Provisions**

Jacking points shall be incorporated at the following locations, with pads supplied for all points:

- a. Forward fuselage
- b. Wings, outboard of nacelles

#### **3.18.3 Mooring Provisions**

Mooring points able to withstand **1.5 g** forces shall be provided at the following locations, with lugs or rings provided for all points:

- a. Nose landing gear
- b. Main landing gear
- c. Wing outer panels
- d. Aft fuselage

#### 3.18.4 Hoisting Provisions

Structural attachment points for hoisting slings shall be incorporated in the following components:

- a. Lift engines (vertical position)
- b. Propulsion engines (horizontal position)

For hoisting the entire airplane, two fuselage locations, forward and aft of the C. G., for girth slings shall be designated by external markings. Slings may also be used for the wing outer panels and horizontal tail.

#### 3.18.5 Leveling

Conventional provisions for measuring and leveling shall be made.

#### 3.18.6 Aircraft Component Cover

Shields shall be provided for the horizontal engine intake and exhaust openings, and for the vertical engine intake openings.

#### 3.18.7 Special Tools and Special Ground Handling Equipment

Contractor design and supply of special tools and ground handling equipment for support of the aircraft before delivery shall be included with the aircraft.

#### 3.18.8 Shipping

The aircraft shall be designed such that it can be air transported in a C-141A cargo aircraft. The entire aircraft with wings removed will be placed on a dolly, then placed aboard and shipped to the contract facility.

#### 3.18.9 Ground Running Screens

Removable screens shall be provided for the horizontal and vertical engine inlets for use in routine ground runnings.

### 3 10 Ground Checkout Cart

A ground checkout cart ( carts) shall be provided for the purpose of calibrations, preflight check and trouble shooting of the SAS and VSS equipment.

#### 3.18.11 Tire Shields

The main landing gear tires shall be protected from heat and erosion during ground running of the lift engines by chocks incorporating blast shields.

#### 3.18.12 Provisions for VTOL Test Stand/Wind Tunnel Mounting.

The aircraft shall have the capability of being mounted to a selected VTOL test stand and in the NASA Ames 40 x 80-foot wind tunnel by attaching to the nose and main landing gear wheel axles to their respective strut trunnion support fittings.

#### **4.0 SAMPLING, INSPECTION AND TEST PROCEDURES**

The contractor shall demonstrate by actual test or by other substantiation that the aircraft and all its installed systems, subsystems and components meet all the requirements of the contract, including applicable specifications and standards. Engineering data shall be furnished the procuring agency in accordance with a separate document, which shall define the extent of qualification testing required.

## 5.0 PREPARATION FOR DELIVERY

The aircraft shall be prepared for delivery as specified by the procuring activity. The preflight checkouts indicated in other sections of this specification shall be conducted by the contractor prior to delivery to ensure the proper operation of all systems and functional components.

APPENDIX 1-APRELIMINARY GOVERNMENT FURNISHED AIRCRAFT EQUIPMENT LISTCONTRACTOR INSTALLED

Only the J85-19 engines, lift-cruise engine diverter valves, and lift engine swivel nozzles have been identified as GFE items for cost and schedule purposes. Past experience has shown that items commonly provided as GFAE-Contractor Installed equipment on larger military production contracts required unsatisfactorily long lead times for experimental shop operations. Although the cost of items may be somewhat lower as GFE, the schedule disruptions usually result in net increases in program costs where extremely limited production is involved.

To provide a basis for NASA's own analysis of the potential savings of maximizing the GFAE (irrespective of schedule), a list of all identifiable equipment for the new and modified concept vehicles which could be anticipated as GFAE items on military production contracts has been included in this Appendix.

ITEM NO.	DESCRIPTION	QUAN./A/C
1	Engine: - YJ 85-19 General Electric Turbojet engine in accordance with a General Electric Specification to be determined by General Electric Company and NASA. Vertical operation of 7 engines and horizontal operation of 2 engines shall be provided. The basic take-off rating of all 9 engines shall be 3015 pounds maximum static uninstalled thrust at sea level, standard day conditions with zero bleed and accessory power extraction, with an exhaust nozzle sized for zero bleed the rating shall be for at least 5 minutes duration.	9

ITEM NO,	DESCRIPTION	QUAN. /A/C
	<p>The following list <b>of</b> engine equipment shall be contained on each engine and is appropriate to the running position <b>of</b> the engine:</p> <ul style="list-style-type: none"> <li>a. Fuel Pump</li> <li>b. Fuel Control</li> <li>c. Oil Tank</li> <li>d. Oil Pump</li> <li>e. Ignition System</li> <li>f. Tachometer Generator</li> <li>g. Starter Connection (low pressure air)</li> <li>h. Engine Thermocouples</li> <li>i. Blanket Insulation, Combustion Chamber</li> </ul>	
2	Swivel Nozzles (lift engines) and Actuators	7
3	Diverter Valve (lift/cruise engine) and actuators	2
4	Accessory Gear <b>Box</b> and Drives (lift/cruise)	2

APPENDIX 1-AGOVERNMENT FURNISHED AIRCRAFT EQUIPMENTINSTRUMENTSCONTRACTOR INSTALLED

ITEM NO.	DESCRIPTION	QUAN./A/C
1	Air Speed/Mach Meter	2
2	Clock (Elapsed Time)	2
3	Vertical Velocity Indicators	2
4	Pressure Altimeter Indicators	2
5	Turn Slip, Side Slip and Lateral Velocity Indicators	2
6	Attitude Indicators	2
7	Bearing Indicators	3
8	Angle of Attack Indicators	2
9	Radar Altimeter	2
10	Standby Compass	2
11	Accelerometer	1
12	Oil Pressure Indicators	4
13	Fuel Management Indicator	1
14	Multiple Tachometer Indicators	3
15	Multiple Exhaust Gas Temp. Indicators	3
16	Multiple Thrust Indicators	4
17	Fuel Quantity Indicator	1
18	Fuel Balance Indicator	1
19	Hydraulic Pressure Indicators	8
20	Duct Pressure Indicators	4

INSTRUMENTS  
(Continued)

ITEM NO.	DESCRIPTION	QUAN.
21	Flap Position Indicators	2
22	Thrust Vector Indicators	2
23	Take-off Trim Indicators	2
24	Gear Position Indicators	2
25	Transmitter Rate of Flow (Fuel)	as re- quired
26	Transmitter Pressure Hydraulic	
27	Transmitter Flap Position	
28	Transmitter Oil Pressure	
29	Indicator, Engine Fire/Fire/Overheat	
30	Diverter Valve Position Indicator	

APPENDIX 1-AGOVERNMENT FURNISHED AIRCRAFT EQUIPMENTELECTRONICSCONTRACTOR INSTALLED

ITEM NO.	DESCRIPTION		QUAN.
1	VORTAC	AN/RNA-26C NAC. REC DMA-29L-DME Antennas	1
2	IFF/SIF	AN/ APX-72 Transponder Antennas	1
3	ILS	MKA-28 Marker Beacon Antennas	1
4	COMMUNICATION	RTA-41B VHF Transceiver	1
5	INTERCOM	Microphone Amplifiers Headset	1
6	COMPASS SYSTEM	Gyro Stabilized Stable Platform Heading Coupler Controllers	1
7	MISCELLANEOUS	Radio "J" Box Noise Filters Antenna Switching Relays Power Supply Coaxial Relay	as re- quired

APPENDIX 1-A

GOVERNMENT FURNISHED AIRCRAFT EQUIPMENT

MISCELLANEOUS

CONTRACTOR INSTALLED

ITEM NO,	DESCRIPTION	QUAN.
	OXYGEN SYSTEM (GASEOUS)	
1	a. Oxygen Quantity Indicator	2
2	b. Bottle	1
3	c. Drain Valve	1
4	d. Combination Valve	2
5	e. Regulator Set	2
6	f. Diluter Demand Regulator	2
1	EJECTION SEAT, (LW-2D Zero Altitude Zero Speed)	2
2	a. Survival Kit	2
3	b. Safety Belt	2
4	c. Harness, Aircraft Safety, Shoulder Adj.	2
5	d. Initiator	2
6	e. Catapult	2
7	f. Initiator	2
8	g. Thruster	2
9	h. Parachute Back-pack Type	2
10	i. Hard Helmet (including) Oxygen Mask	2
1	AIR CONDITIONING UNIT	1
2	Fan and Blowers	as re-
3	Ram Air Valves	quired

APPENDIX 1- A

GOVERNMENT FURNISHED AIRCRAFT EQUIPMENT

ELECTRICAL

CONTRACTOR INSTALLED

ITEM NO.	DESCRIPTION	QUAN.
1	Receptacle, External Power	1
2	Generator	2
3.	Voltage Regulator	2
4	Reverse Current Dropout Relay	2
5	Static Inverter	2
6	Relay External Power	1
7	Vibrator	2
8	Battery Relay	1
9	Converter	2
10	Relays (Power Contactors)	3
11	Current Transformers (Power Control)	2
12	Battery	1

APPENDIX 1-A

GOVERNMENT FURNISHED AIRCRAFT EQUIPMENT

ALIGHTING GEAR

CONTRACTOR INSTALLED

ITEM NO.	DESCRIPTION	QUAN.
1	Nose Gear (A-4E), Modified, and Wheel Assy.	1
2	Main Gear	2
	a. Wheels (F-5A) Mod.	
	b. Tires (F-5A)	
	c. Brakes (F-5A) Mod.	

APPENDIX 1-A

GOVERNMENT FURNISHED AIRCRAFT EQUIPMENT

FUEL AND  
HYDRAULIC SYSTEM

CONTRACTOR INSTALLED

ITEM NO.	DESCRIPTION	QUAN.
	HYDRAULIC SYSTEM	
1	Pump, Variable Volume	4
2	Reservoir	2
3	Hydraulic Oil Cooler (Oil to Air)	2
4	Accumulator (Bendix)	2
5	Valve, Flow Regulator	as re- quired
6	Valve, Hyd, Stability Augmenter Shutoff	
7	Valve, Hyd, Pump Unloading	
	Regulator, Air Pressure Hyd	
	FUEL SYSTEM	
1	Filler Cap Adapter	1
2	Pressure Relief Valve	1
3	Strainer (Including By-pass Indicators)	as re- quired
4	Motor-operated Fuel Shutoff Valve	10
5	Pump, Transfer Boost	4

APPENDIX 1-A

GOVERNMENT FURNISHED AIRCRAFT EQUIPMENT

STAB. AUG. SYSTEM

CONTRACTOR INSTALLED

ITEM NO,	DESCRIPTION	QUAN.
	(SAS)	
1	Auto-flight Control, Three Axis SAS, (A-7A)	1
2	Gyros - Rate	
	Single Channel Servo Actuators	6
	Solenoid Shut-off Valves	6
3	Controller	2
4	Electronic Package	1
	VSS	
1	Aeroflex Sensors	1
2	Aeroflex Unit and Ind.	1
3	Three <i>Axis</i> Accelerometers	
	a. Angular	3
	b. Translation	3
4	Attitude Gyro	1
5	Airborne Computer	1
6	Autopilot Unit	1
7	Cockpit Controllers	1
8	Transducers	as re-
9	Parallel Actuators	quired 5
10	Radar Altimeter (Complete)	1
11	Doppler Radar	1

APPENDIX 1-A

GOVERNMENT FURNISHED AIRCRAFT EQUIPMENT

CONTROLS

CONTRACTOR INSTALLED

ITEM NO.	DESCRIPTION	QUAN.
1	B8A Stick <b>Grip</b>	2
2	Horizontal Tail Hydraulic Servo Actuator	2
3	Force Feel Trim Actuator	3
4	Rudder and Aileron Servo Actuator	4

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## **APPENDIX II**

### **DEVIATIONS**

In accordance with Paragraph 2.1 herein, government documents shall be applicable only as guides in the design of the flight research vehicle, except where the requirements may directly affect flight or safety.

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## APPENDIX III: VSS AND SAS SPECIFICATION

### 111-1.0 INTRODUCTION

This specification describes the design and performance requirements of the flight control system for V/STOL Jet Operations Research Airplane N-309, including the stability augmentation system (SAS), the variable stability system (VSS), and appropriate ground support hardware. Specifications covering the cockpit flight controls and the primary flight controls are defined in the main body of the aircraft Model Specification, but some requirements are restated in this appendix for clarity.

The intent herein is to specify state of the art, fully qualified hardware where possible to minimize cost and delivery time. It is intended that the system will be primarily assembled from existing equipment with only minor modifications to some components. The detailed hardware design and packaging of the variable stability equipment will reflect experimental-type flight hardware rather than refined operational-type equipment.

#### 111-1.1 APPLICABLE DOCUMENTS

The following documents, of the issue in effect on the date of invitation for bids, shall be used wherever applicable in the design, installation, and operation of the flight control equipment.

MIL-C-18244	Control and Stabilization Systems: Automatic, Piloted Aircraft, General Specification for
AGARD REPORT 408	Recommendations for V/STOL Handling Qualities
MIL-F-8785	Flying Qualities of Piloted Aircraft

### III-2.0 STABILITY AUGMENTATION SYSTEM (SAS)

The augmentation system shall provide those control functions which are required to improve the stability and handling characteristics of the aircraft. The SAS shall operate during hover ( $\pm 35$  knots), transition (up to conversion), and conventional flight (up to  $M = 0.8$ ,  $h = 25,000$  feet).

#### III-2.1 GENERAL DESCRIPTION

Stability augmentation shall be provided in three axes: pitch, roll, and yaw. A dual-redundant rate feedback system with a fixed compensation and a variable gain defines the SAS complexity in each axis, see Figure III-1. The gain shall be programmed as a function of  $\bar{q}$ , dynamic pressure. The rate feedback shall be sensed by two gyros in each channel (a total of six gyros will be needed for all three channels). To preserve reliability and independence from the VSS, the SAS shall be designed as a separate unit. However, in order to reduce the VSS cost, some external components, such as the rate gyros, shall be shared between the two systems. Feedback paths shall be provided between the pitch and roll SAS channels to neutralize unwanted effects due to engine gyroscopic coupling. This cross-coupling feedback shall be automatically removed at the end of transition.

#### III-2.2 SAS REQUIREMENTS

Handling qualities of the augmented airplane shall satisfy at least the minimum recommendations of AGARD Report 408 (NASA modified, NAS1-6777) for hover and transition flight. Damping of oscillatory modes in conventional flight shall be governed by the requirements of MIL-F-8785.

Dual redundancy in all SAS channels shall provide fail-operate characteristics. Failure mode-detection and indicators of the SAS operation shall be provided for pilot monitoring.

#### III-2.3 DESIGN AND PACKAGING

SAS Flight control elements shall use, where possible, repackaged or modified hardware available from flight-proven production designs. Where new designs

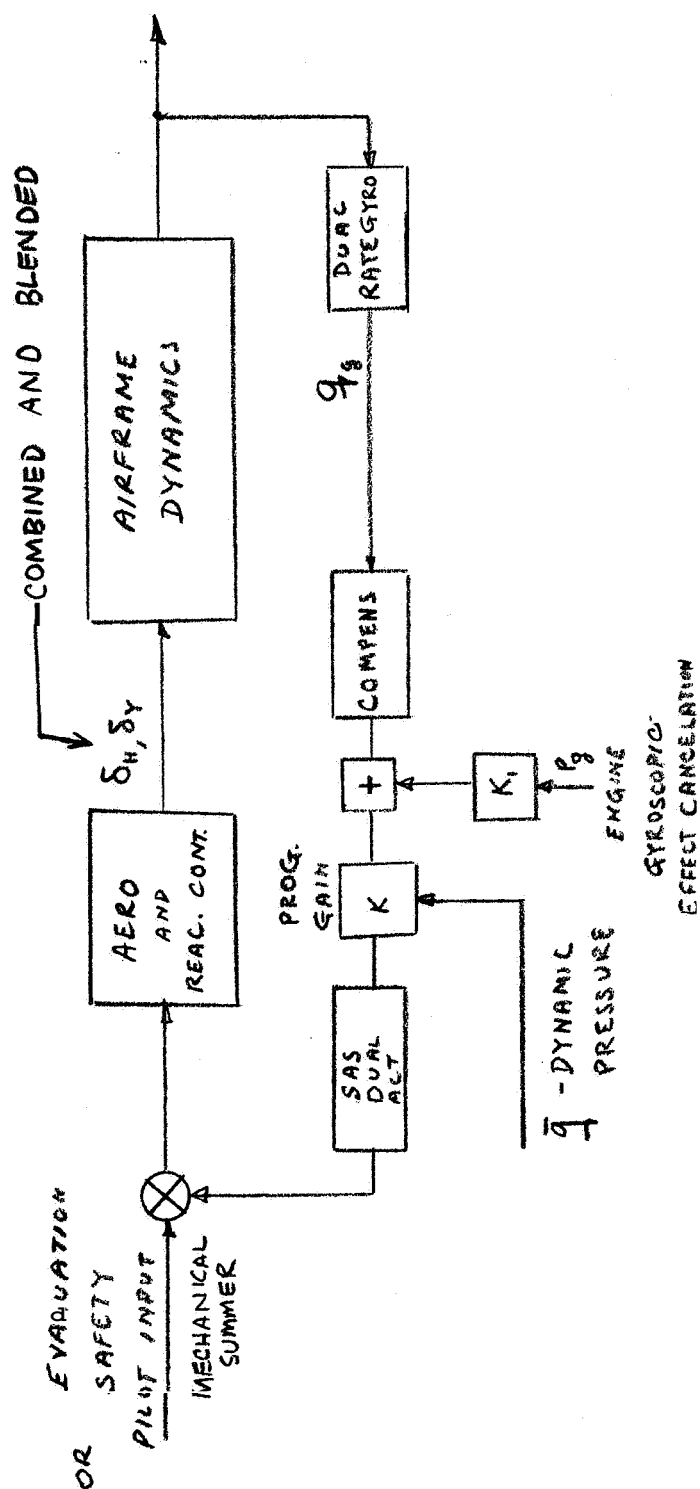


FIGURE III-1. PITCH SAS CHANNEL

are unavoidable, only designs based on flight-tested criteria and specifications shall be used. All flight control elements shall be designed to conform to the requirements of MIL-C-18244A, unless specifically approved by the procuring agency. The actual testing requirements of MIL-C-18244A shall be used only to establish design criteria.

Figure III-2 shows proposed SAS packaging.

#### III-2.4 EQUIPMENT LIST

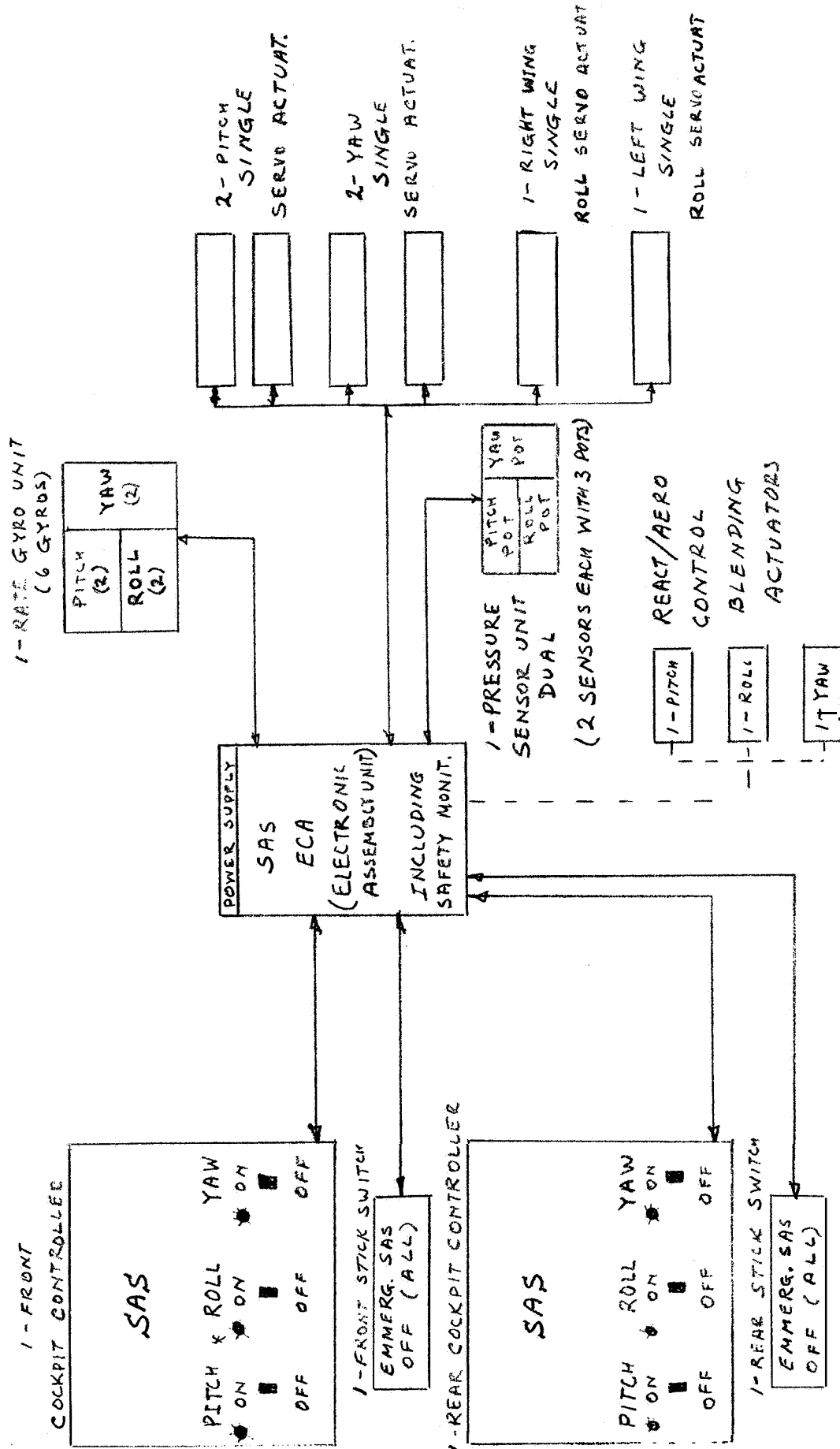
The Stability Augmentation System will be composed of the following units:

- 1 - Electronic assembly unit (ECA)
- 1 - SAS front cockpit controller
- 1 - SAS rear cockpit controller
- 1 - SAS front stick emergency disconnect switch
- 1 - SAS rear stick emergency disconnect switch
- 1 - SAS rate gyro package (6 rate gyros)
- 2 - SAS pitch single servo actuators
- 2 - SAS yaw single servo actuators
- 2 - SAS roll single servo actuators
- 3 - Reaction/aero blending actuators
- 1 - Pressure sensor unit, dual (6-sensor with 6 potentiometers)

#### III-2.5 INTERFACE

The Stability Augmentation System will have the following interfaces:

- ECA with **SAS** Front Cockpit Controller
- ECA with **SAS** Rear Cockpit Controller
- ECA with SAS Front Stick Emergency Disconnect Switch
- ECA with SAS Rear Stick Emergency Disconnect Switch
- ECA with SAS Rate Gyro Package
- ECA with SAS Pitch Two Single Actuators



6A-3

III-5

\* INDICATOR LIGHT TYPICAL

FIGURE III-2. STABILITY AUGMENTATION SYSTEM (SAS) HARDWARE DISTRIBUTION

- ECA with SAS Roll Two Single Actuators
- ECA with SAS Yaw **Two** Single Actuators
- ECA with Pressure Sensor Unit, Dual ( $\bar{q}$ -sensor)
- ECA with VSS Cockpit Controller

III-2.6 WEIGHT

Total Stability Augmentation System weight shall not exceed 80 pounds (as described in 2.4, installation excluded). The desired total weight is 118 pounds and is distributed as follows:

SAS alone	
(as described in 2.4)	- - - - - 57 pounds
Plumbing, cables and brackets	- - - - - 61 pounds
SAS Total	- - - - - 118 pounds

III-2.7 POWER

Total Stability Augmentation System electrical power consumption shall not exceed 300 watts. The desired target power consumption is 220 watts.

### III-3.0 VARIABLE STABILITY SYSTEM (VSS)

The Variable Stability System shall provide airborne hover and transition simulation of various types of V/STOL jet aircraft. The function of the VSS shall be to control automatically five-degree-of-freedom motion response of the basic VTOL aircraft in precise phase and amplitude corresponding to electrical signals computed in the onboard reference model. The VSS shall be "modified model type" with some forward and feedback compensation with appropriate switching modes.

#### 111-3.1 GENERAL DESCRIPTION

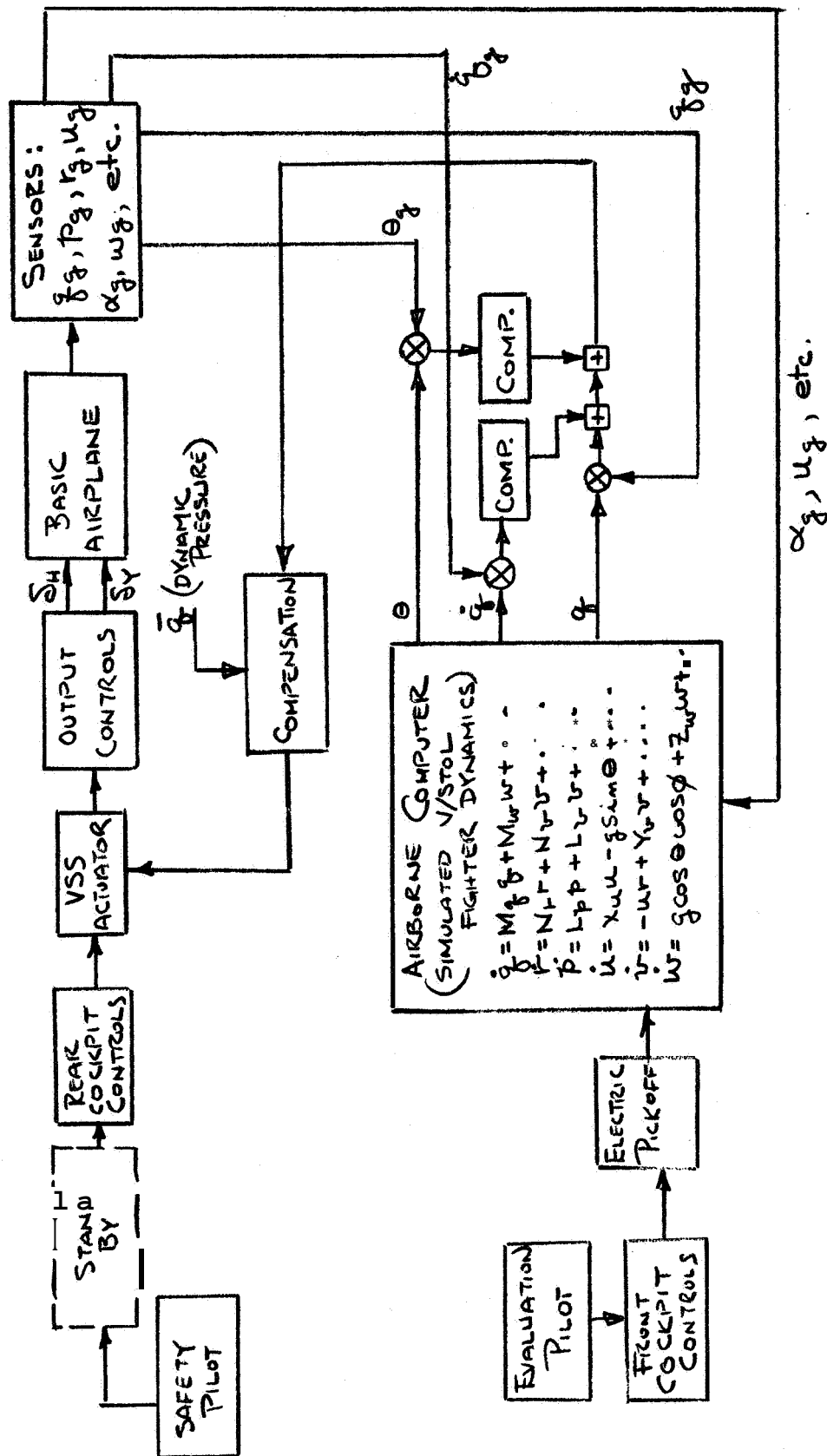
The Variable Stability System is basically a model following type with some forward and feedback compensations. **\*Six** degrees of freedom equations of motion, which simulate the dynamics of the selected V/STOL fighter, will be solved by an airborne computer. Five degrees - pitch rate, roll rate, yaw rate, forward velocity and vertical velocity, however, will be used to drive and force the basic airplane to follow the model.

Figure 111-3 shows the pitch channel in VSS mode. In this mode, the evaluation pilot (front cockpit) is in command of the aircraft, while the safety pilot is in standby (rear cockpit). The cockpit controls of the evaluation pilot are "mechanically" disconnected from the aircraft primary controls. The only connection is through electrical wires, which implies that the pilot "flies by wire" only (F.B.W.). The electrical pickoffs (on the cockpit controls) transmit the pilot commands directly to the airborne computer. A number of sensors (such as angle of attack, altimeter, etc.) also supply information to the computer. These sensors supply the computer with the fundamental information, primarily about the motions generated by the basic airplane.

A command signal is created as soon as the equations of motion of the simulated fighter are solved in real time by the computer. In the pitch channel, as

---

\*NOTE: Six degrees were used for computer sizing. Five degrees will be mechanized.



**FIGURE III-3. VSS PITCH CHANNEL**

Figure 111-3 shows, this commanded signal is defined as a pitch rate,  $q$ . When the pitch rate is compared with the gyro output,  $q_g$ , a definite error signal is generated.

The error signal is amplified and then used through the VSS actuator to drive the primary controls of the basic airplane.

In order to overcome unavoidable lags in the computer and the control system, the model following technique will require some form of compensation. The basic technique selected to achieve this depends on forcing a match between sensed and computed acceleration and attitude as well as rate. In general, the acceleration match will force the high frequency response and the attitude match the low frequency response. This method will effectively reduce high frequency lags or low frequency drifts which would otherwise exist between the computed pitch motion and the actual pitch motion.

Because of compensation, the closed loop gain can be substantially increased, but not without programmed gain. Figure 111-3 shows that the gain is programmed as a function of  $\bar{q}$ , dynamic pressure.

### 111-3.2 APPLICABLE DOCUMENTS

- (1) NASA RFP L-7151 V/STOL Jet Operations Research  
Airplane Design Study
- (2) Norair Study Reports I, II, III  
NASA V/STOL Jet Operations  
Research Airplane, NASI-6777
- (3) Aeroflex Laboratories, Inc. , Model ARX VD-1  
Air Speed Sensor Model Specification
- (4) Aeroflex Laboratories, Inc., Model ARX VD-1  
Indicator Model Specification
- (5) Airborne Digital Computer Model Specification  
(Teledyne and G. E. Manuals)
- (6) Doppler Radar, body-mounted antenna  
(GPL and LFE manuals)
- (7) Radar Altimeter (altitude and rate of descent)  
(Ryan and Honeywell manuals)

### **III-3.3 REQUIREMENTS**

#### **111-3.3.1 Operation**

VSS shall operate in hover, transition, and at speeds up to **250** knots.

**III-3.3.1.1** VSS capability during hover and during transition up to  $V_{con}$  shall be in five degrees of freedom (pitch, roll, yaw, forward translation and vertical translation).

**111-3.3.1.2** VSS capability from  $V_{con}$  up to **250** knots shall be in four degrees of freedom (pitch, roll, yaw, and forward translation).

**111-3.3.1.3** The VSS shall model follow in either direct-lift, or composite-lift transition modes.

**111-3.3.1.4** The VSS shall operate from ground level to **5,000** feet altitude, when using five degrees of freedom.

**111-3.3.1.5** The VSS shall be able to operate in winds not in excess of **35** knots.

**III-3.3.1.6** The VSS shall be operated and controlled from the Evaluation Pilot controls.

**III-3.3.1.7** The VSS operation shall be overpowered by the Safety Pilot Controls.

**III-3.3.1.8** During VSS operation, the Evaluation Pilot cockpit controls electrical outputs, and/or airborne computer commands, and/or auto-pilot commands, shall always move the Safety Pilot cockpit controls. This applies to pitch, roll, yaw, and two throttles (one for all lift/cruise, one for all lift engines) cockpit controls. Only indicators will be provided for Safety Pilot monitoring of diverter valve and vector positions.

**III-3.3.1.9** The VSS shall either operate each channel separately (see **III. - 3.3.1.1**, and **III. -3.3.1.2**), or any combination of two, three, or all channels simultaneously within the specified VSS limits.

**III-3.3.1.10** The VSS shall have provisions for in-flight switching from one mode to another (see **III. -3.7.2.2**).

**III-3.3.1.11** The VSS shall have safety provisions.

**III-3.3.1.12** The VSS performance shall be defined by the delay which can be measured between the simulated and the basic rates in real time. Effort shall be directed to reduce this delay to 0.1 second or less.

**III-3.3.1.13** The VSS shall have provisions for in-flight authority control in each channel (pitch, roll, yaw, vector, and for throttles: one for all lift/cruise and one for all lift) from **30%**to 100%.

#### **III-3.4** VSS LIMITATIONS

##### **III-3.4.1** Weight

The total VSS weight (including installation) shall not exceed **500** lbs. The desired uninstalled weight is **245** lbs.

### III-3.4.2 Electrical Power

Total electrical power consumption by the VSS shall not exceed 1,800 watts.

### 111-3.4.3 Environment Limitation

111-3.4.3.1 The VSS shall operate without damage at the following noise levels:

- (a) Outside the Aircraft - the expected noise level is 150 db, and
- (b) In the VSS Compartment - the expected noise level is 110 db.

III-3.4.3.2 The VSS shall not be damaged by the following:

- (a) The expected maximum normal acceleration is  $3.75g$ ,  $-1-1/2g$ .
- (b) The expected maximum lateral acceleration is  $\pm 1g$ .
- (c) The maximum speed  $M = 0.8$ .
- (d) The maximum altitude  $H = 25,000$  feet.
- (e) The maximum pressure equivalent to  $M = 0.8$ ,  $h =$  sea level  
(Approx.  $= 1,110 \text{ lb/ft}^2$ ).

III-3.4.4 The VSS shall not be turned on when the mechanical interconnect exists between the Safety and the Evaluation Pilot cockpit controls on any axis so connected.

### III-3.5 PACKAGING

#### III-3.5.1 VSS Packaging

The VSS equipment shall be assembled from existing equipment where possible. It should be based on an experimental breadboard setup, rather than on a refined operational package approach. The VSS packaging is shown in Figure III-4.

#### III-5.3.2 Throttle Control

The throttle control channel subsystem shall have only electrical commands and shall control the engine throttles of all lift engines and of two lift/cruise engines. Since this control subsystem will be used by either the safety, or by the evaluation pilot (including VSS commands), a refined operational packaging approach shall be used with all safety provisions. Figure III-5 shows the proposed packaging for the throttle control subsystem.

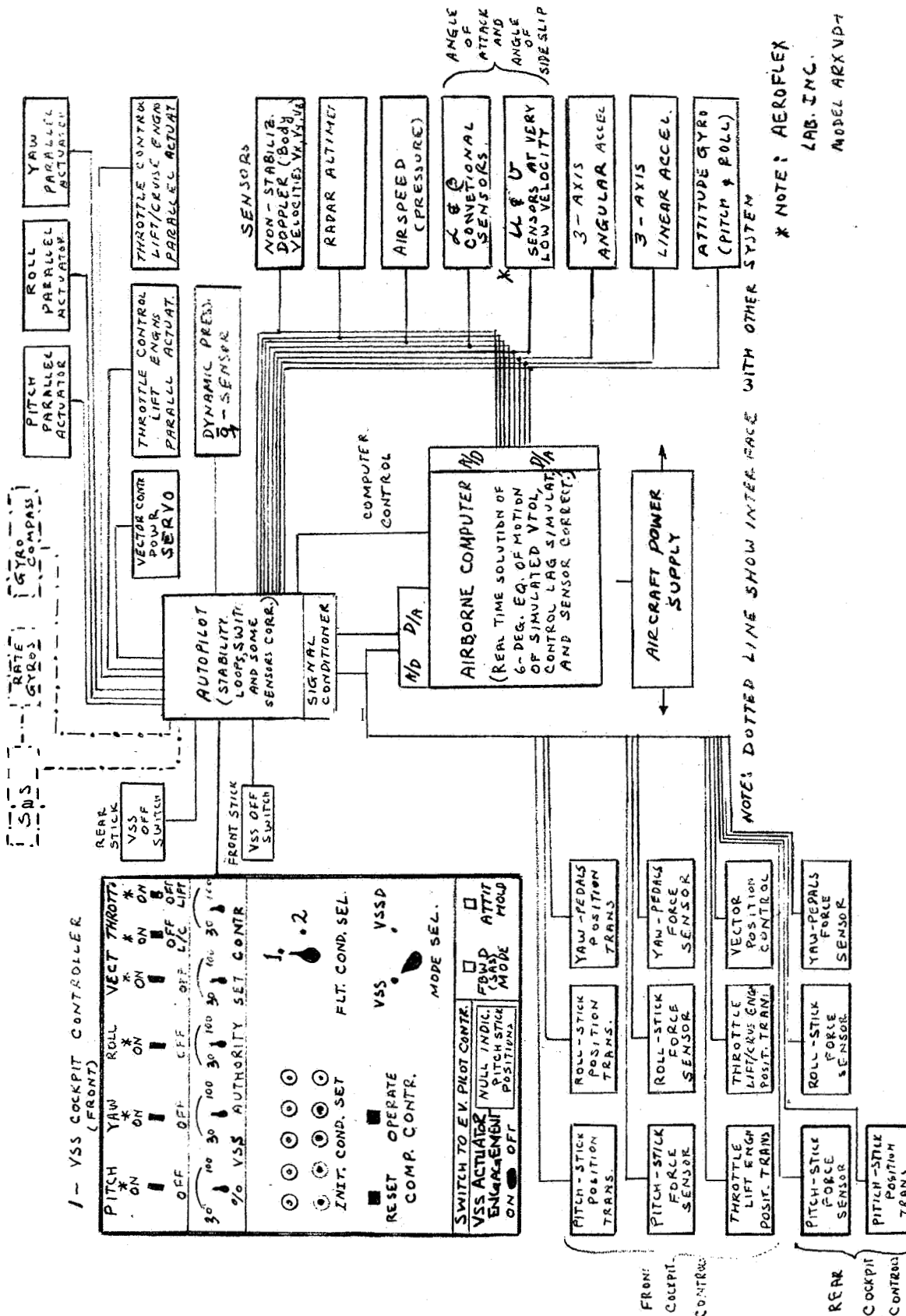


FIGURE III-4. VARIABLE STABILITY SYSTEM (VSS) HARDWARE DISTRIBUTION

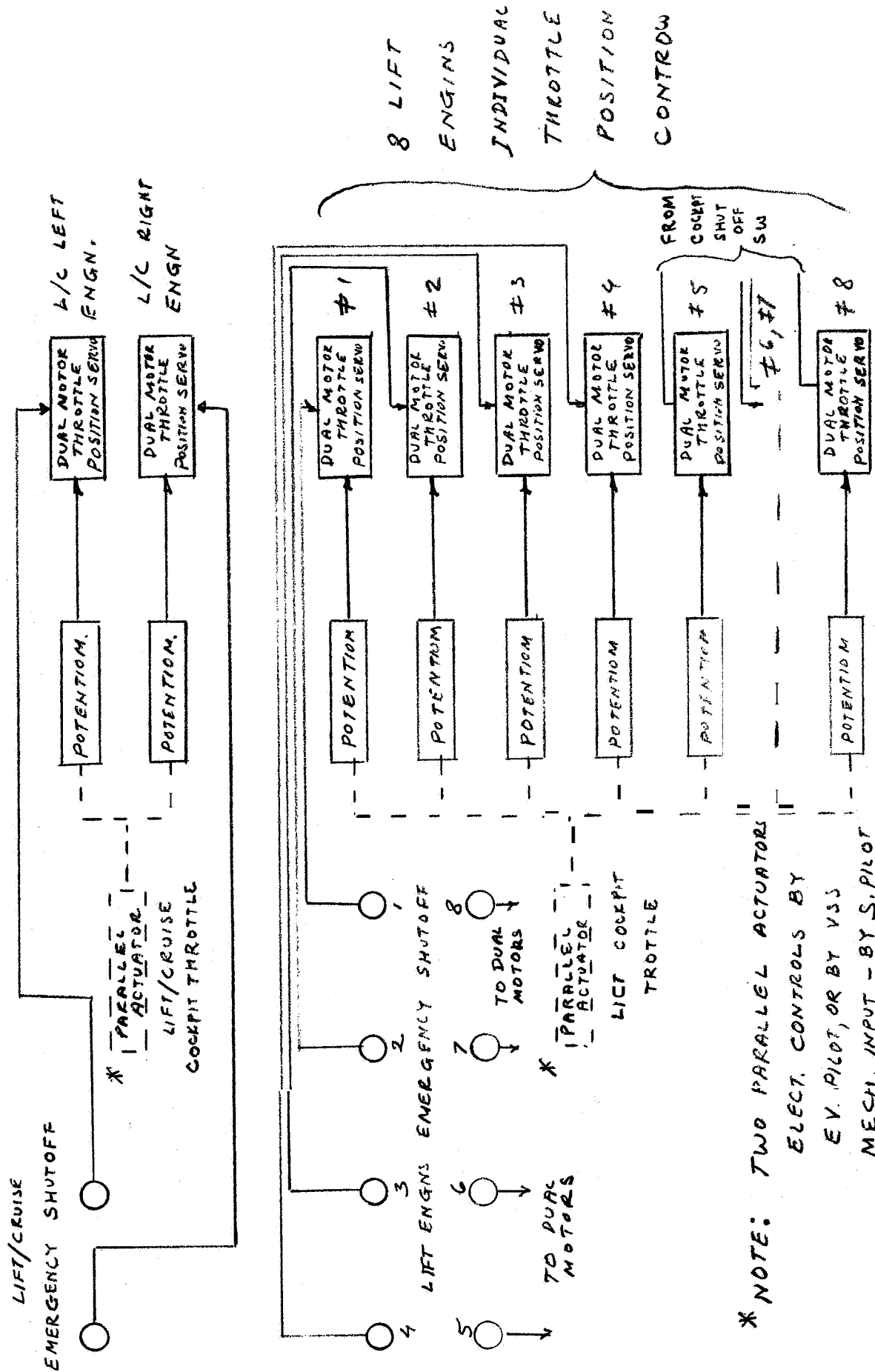


FIGURE III-5. TYPICAL LIFT/CRUISE AND LIFT ENGINE THROTTLE CONTROL SUBSYSTEMS

### III-3.5.3 Vector Control

The vector control channel subsystem shall be operated on all-electrical commands and control the positions of all lift engine nozzles. All hydraulic actuators will be attached to the nozzles and will be supplied by General Electric. However, the actuators will be supplied by G. E. without the valves. Since this control subsystem will be used by either the safety or by the Evaluation Pilot (including VSS commands), a refined operational packaging approach shall be used with all safety provisions. Figure 111-6 shows the proposed packaging for the vector control subsystem.

### III-3.6 EQUIPMENT LIST

#### III-3.6.1 VSS Equipment List

The Variable Stability System will be composed of the following units:

- 1 - Airborne computer with power supply
- 1 - Autopilot unit with power supply
- 1 - VSS cockpit controller
- 1 - Front stick emergency VSS disconnect switch
- 1 - Rear stick emergency VSS disconnect switch
- 2 - Pitch-stick position transducers
- 1 - Roll-stick position transducer
- 1 - Yaw-pedals position transducer
- 2 - Pitch-stick force sensors
- 2 - Roll-stick force sensors
- 2 - Yaw-pedal force sensors
- 1 - Throttle lift engine cockpit controller position transducer
- 1 - Throttle lift/cruise engine cockpit controller position transducer
- 1 - Vector (engine nozzles) cockpit controller position transducer
- 1 - Pitch parallel actuator
- 1 - Roll parallel actuator
- 1 - Yaw parallel actuator
- 1 - Throttle control lift engines parallel actuator
- 1 - Throttle control lift/cruise engines parallel actuator
- 1 - Vector control power servo amplifier
- 1 - Dynamic pressure,  $\bar{q}$ -sensor
- 1 - Doppler sensor, non-stabilized (body velocities:  $V_x, V_y, V_z$ )

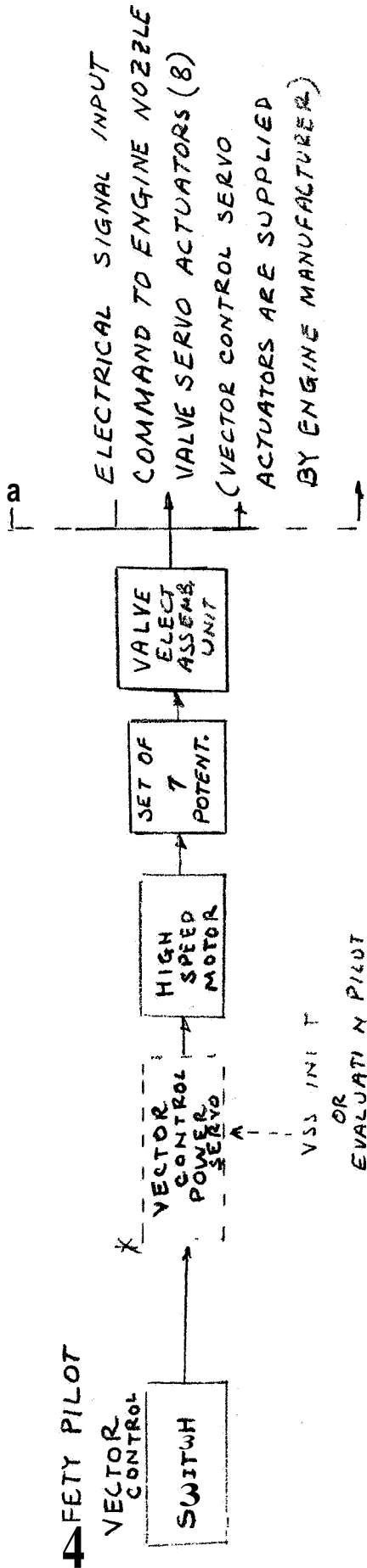


FIGURE III-6. TYPICAL VECTOR CONTROL SUBSYSTEM  
V  
TYPICAL

- 1 - Radar altimeter (Altitude and rate of descent outputs)
- 1 - Altitude Pressure Altimeter
- 1 - Airspeed pressure sensor
- 1 - Conventional  $\alpha$  and  $\beta$  sensor (angle of attack and side slip)
- 1 - u and v (forward, side) freestream velocity sensor at very low ground speeds - Aeroflex unit
- 1 - 3-axis angular accelerometer unit
- 1 - 3-axis translational accelerometer unit
- 1 - Attitude gyro (pitch and roll)
- 1 - Heading (may be used from NAV. system)
- 1 - Left roll nozzle position
- 1 - Right roll nozzle position
- 1 - Pitch nozzle position
- 1 - Yaw nozzle position
- 3 - Throttle position (engine RPM, thrust)
- 6 - Bleed air pressure (from selected lift and L/C engines)
- 6 - Bleed air temperature

#### **111-3.6.2    Throttle Control Subsystem (Lift and L/C Engines) Equipment List**

The throttle control subsystem shall consist of the following units:

- 10 - Emergency shutoff switches (8 for lift engine, 2 for L/C)
  - 1 - Unit with 8 potentiometers (for lift engine servo)
  - 1 - Unit with 2 potentiometers (for L/C engine servo)
- 10 - Dual motors to position throttles

#### **111-3.6.3    Vector Control Subsystem (Lift Engine Nozzles Only) Equipment List**

The Vector Control Subsystem shall be composed of the following units:

- 1 - Cockpit vector control (switch)
- 1 - High speed torque motor
- 1 - Set of 8 potentiometers unit
- 1 - Valve electronics assembly unit
- 2 - Cockpit displays, vector position
- 8 - Electrohydraulic valves

### **III-3.7    PRELIMINARY VSS SUBSYSTEM SPECIFICATIONS**

#### **III-3.7.1    Airborne Computer**

III-3.7.1.1 SCOPE. The airborne computer provides the capability for simulation of wide ranges of V/STOL jet aircraft. ~~The~~ computer will be primarily used to solve the equations of motion of an aircraft in real time. In addition to this, the computer will be used to perform necessary corrections to the sensors' signals, and functional modification to all pilot's controls outputs - all in real time.

The computer must be flexible in respect to "Soft Ware" - and shall be easily reprogrammed.

111-3.7.1.2 COMPUTER TYPE. The airborne computer shall be a fast "on-line" digital computer (with real time solution capability). The digital computer must have Analog to Digital (A/D) and Digital to Analog (D/A) conversion input/output devices for all signals (except for signals which are already digital, or for computer controls).

111-3-7.1.3 COMPUTER GENERAL DESCRIPTION. The digital airborne computer is the heart of the VSS. The computer will be mechanized such that programming of a VSS V/STOL simulation will be greatly simplified. The computer will be composed of a flexible and a fixed portion. See Figure III-7. The fixed portion of the computer will perform sensor correction and sensor switching; VSS-autopilot modes and associated logics; signal cancellations. The flexible portion of the computer will be used to simulate a variety of control dynamics; the range of V/STOL jet airplane dynamics (6-degrees of freedom capability); to perform forward and feedback signal simulation and compensation - the "wired feedback," thus generating error command signals to the actuators -- the "aircraft muscles"; to make summation of control inputs and sensor outputs -- the "Patch Boards." The "Patch Board," or Variable Stability System Direct (VSSD) mode will always bypass the Equations of Motion and signals go directly to the actuators. The Variable Stability System (VSS) mode will include equations of motion and signals go through the optimized "wired feedback" portion before going to the actuators. All gains and compensation are programmed as functions of dynamic pressure and can be adjusted by the operator.

111-3.7.1.4 COMPUTER COMPLEXITY. The computer shall have enough memory to perform calculations specified on Figure III-8 and Figure III-9, and Figure III-10; or Figure 111-8, and Figure III-11 and Figure III-12, whichever is more complex. The computer must have enough flexibility so the programmer can change the hover equations (Figure III-9) into transition equations (Figure III-11), or the transition equations

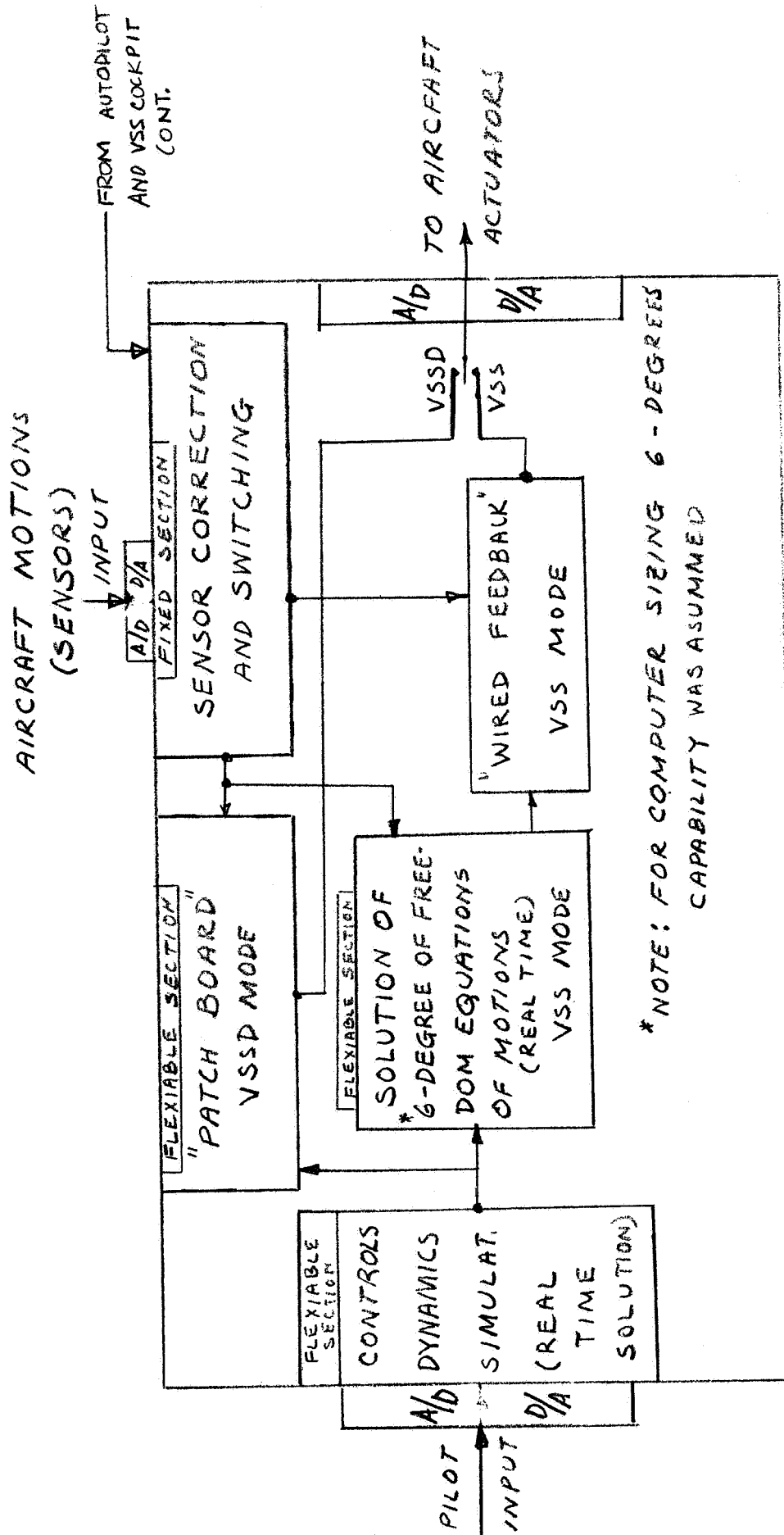
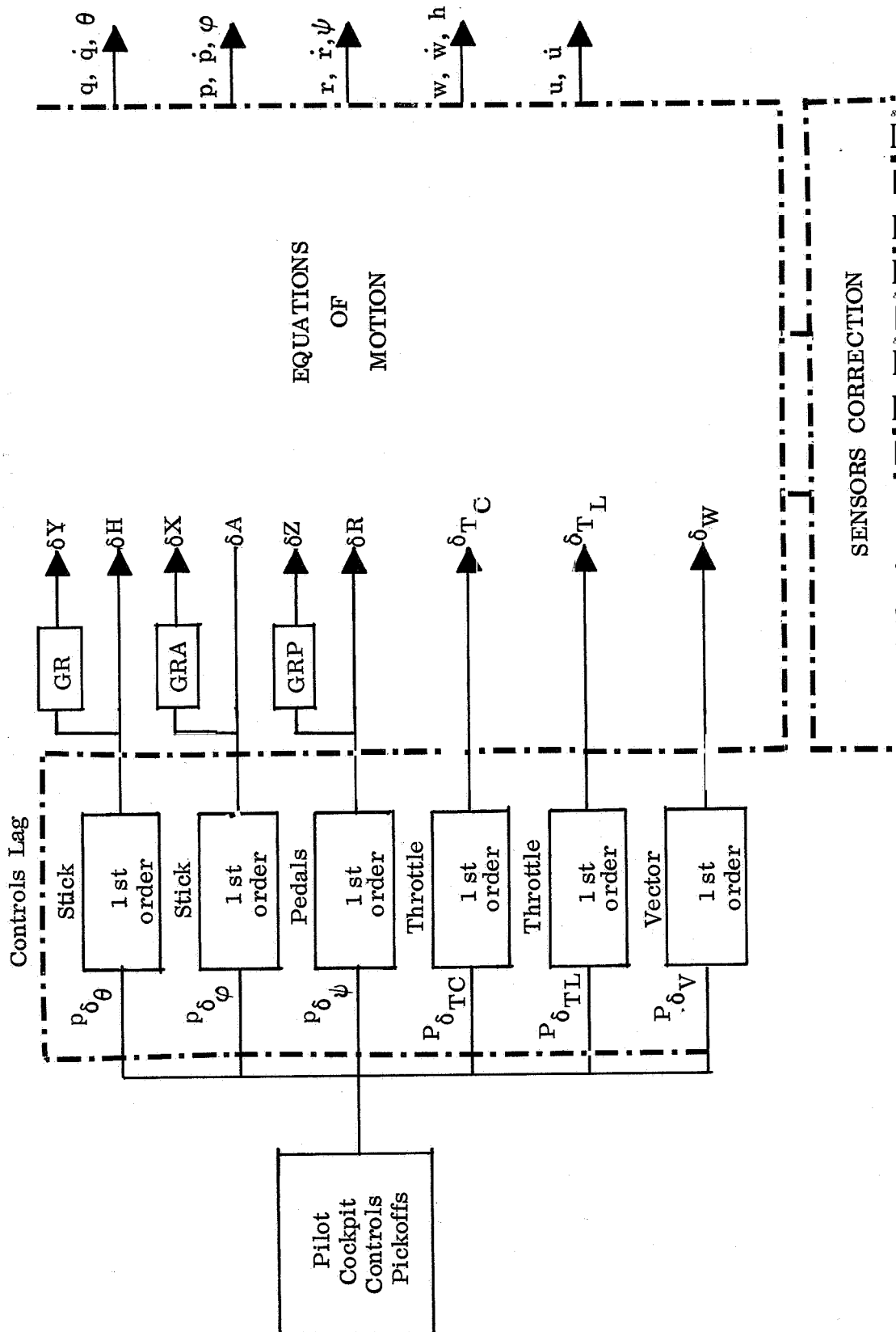


FIGURE III-7. AIRBORNE COMPUTER



Assumptions:

1. One set of equations will be mechanized for simulation (either hover, or transition)
2. Sensors correction will take 20 percent of output  $\pi$  near  $\delta\theta$  to mechanize equation of motion.

FIGURE III-8.

## HOVER

## EQUATIONS OF MOTION FOR AIRBORNE COMPUTER

(BODY AXIS)

$$(1) \quad \dot{u} = -g \sin \theta + X_u u + X_w \delta_w + X_{\dot{w}} \delta_{\dot{w}} + X_{\dot{w}C} \delta_{\dot{w}C} + X_{\dot{w}L} \delta_{\dot{w}L} + X_o \delta_o$$

$$(2) \quad \dot{v} = g \cos \theta \sin \phi + \dot{z}_v v + Y_v \delta_z$$

$$(3) \quad \dot{w} = \overbrace{g \cos \theta \cos \phi}^{G.EF.} + \overbrace{Z_Z \dot{H} + Z_W \dot{w} + Z_{\dot{w}C} \delta_{\dot{w}C} + Z_{\dot{w}L} \delta_{\dot{w}L}}^{N.IN.} + Z_{\dot{w}} \delta_{\dot{w}} + Z_{\dot{w}X} \delta_{\dot{w}X} + Z_o \delta_o$$

$$(4) \quad \dot{p} = \overbrace{L_p p + L_v v + L_q q}^{E.CR.} + \overbrace{L_{XZ} \dot{r}}^{I.CR.} + \overbrace{L_Z H + L_\phi \phi}^{G.EF.} + \overbrace{L_\gamma \dot{\gamma}_2}^{N.IN.} + L_{\delta_X} \delta_X + L_{\delta_Z} \delta_Z$$

$$(5) \quad \dot{q} = M_q q + M_w w + M_u u + M_{Z_H} \dot{H} + M_{\gamma_3} \dot{\gamma}_3 + M_{\delta_Y} \delta_Y + M_{\delta_W} \delta_W + M_{\delta_{TL}} \delta_{TL} + M_{\delta_{TC}} \delta_{TC}$$

$$(6) \quad \dot{r} = \overbrace{N_r r + N_v v + N_\gamma \dot{\gamma}_4}^{N.ZN.} + \overbrace{\dot{w}_Z}^{N.} \delta_Z$$

$$(7) \quad \dot{\phi} = p$$

$$(8) \quad \dot{\theta} = q$$

$$(9) \quad \dot{\psi} = r$$

UNITS		LEGEND	ASSUMPTION
$\theta, \phi, \psi$ - in degrees/second		G. EF - Ground Effect	H - Altitude - is measured
$q, p, r$ - in degrees/second		E. CR - Engr. Cross Coup	
$\dot{q}, \dot{p}, \dot{r}$ - in degrees/seconds <sup>2</sup>		I. CR - Inert. Cross Coup	
All controls, $\delta_X, \delta_Y, \delta_Z, \delta_W,$ $\delta_{TC}, \delta_{TL}, \delta_H, \delta_A, \delta_R,$ are in degrees		N. IN - Noise or Gust Input	All derivatives contain mass and inertia, for example $X_u = \frac{X}{u}$

FIGURE III-9

HOVER SIMULATIONLIST OF FUNCTIONS (Not Included  $g \cos \theta$ , etc.)(EQUATIONS OF MOTIONS)

$$X_{\delta_W} - f_1(1)$$

$$M_{\delta_C} - f_{17}(1)$$

$$X_{\delta_{TC}} - f_2(1)$$

$$N_{\delta_Z} - f_{18}(2)$$

$$X_{\delta_{TL}} - f_3(1)$$

$$L_Z - f_{19}(2)$$

$$Y_{\delta_Z} - f_4(1)$$

$$L_{\varphi} - f_{20}(1)$$

$$Z_Z - f_5(1)$$

$$Z_{\delta_{TC}} - f_6(1)$$

$$Z_{\delta_W} - f_7(1)$$

All others are assumed constant  
(constant multipliers)

$$Z_{\delta_{TL}} - f_8(1)$$

$$Z_{\delta_Y} - f_9(1)$$

$f(1)$  - function of one variable

$f(2)$  - function of two variables

$$Z_{\delta_X} - f_{10}(1)$$

$$L_{\delta_X} - f_{11}(1)$$

$$L_{\delta_Z} - f_{12}(1)$$

$$H_Z - f_{13}(1)$$

$$M_{\delta_Y} - f_{14}(1)$$

$$M_{\delta_W} - f_{15}(1)$$

$$M_{\delta_{TL}} - f_{16}(1)$$

FIGURE III-10

TRANSITION  
EQUATIONS OF MOTION FOR AIRBORNE COMPUTER  
(BODY AXES)

$$\begin{aligned}
 (1) \quad \dot{u} &= -g \sin \theta + X_u(u) + X_w^w + X_{\delta_W} \delta_W + X_{\delta_{MC}} \delta_{MC} + X_{\delta_{ML}} \delta_{ML} + X_{\delta_{OT}} \delta_{OT} \\
 (2) \quad \dot{v} &= (u) r / 57.3 + g \cos \theta \sin \theta + Y_v v + Y_u(u) + Y_{\delta_R} \delta_R + Y_{\delta_Z} \delta_Z + p w / 57.3 \\
 (3) \quad \dot{w} &= (u) q / 57.3 + g \cos \theta \cos \theta + Z_w^w + Z_u(u) + Z_{\delta_H} \delta_H + Z_{\delta_Y} \delta_Y + Z_{\delta_X} \delta_X + Z_{\delta_W} \delta_W + Z_{\delta_{ML}} \delta_{ML} \\
 &\quad + p v / 57.3 + Z_{\delta_{MC}} \delta_{MC} + Z_{\delta_{ML}} \delta_{ML} + Z_{\gamma_1} \gamma_1 \\
 (4) \quad \dot{p} &= \overbrace{L_p^p + L_q^q + L_v^v + L_{XZ}^v}^{I.C.R.} \dot{r} + L_{\delta_R} \delta_R + L_{\delta_A} \delta_A + L_{\delta_X} \delta_X + L_{\delta_Z} \delta_Z + \overbrace{L_{\gamma_2}^{\gamma_2}}^{N.IN} + L_{XZ}^{\rho q} \\
 (5) \quad \dot{q} &= M_q^q + M_w^w + M_u(u) + M_r^r + M_{\delta_H} \delta_H + M_{\delta_Y} \delta_Y + M_{\delta_W} \delta_W + M_{\delta_{TC}} \delta_{TC} + M_{\delta_{TL}} \delta_{TL} + \overbrace{M_{\gamma_3}^{\gamma_3}}^{N.IN} - M_{XZ}^{\rho^2} \\
 (6) \quad \dot{r} &= N_r^r + N_v^v + N_q^q + N_{\delta_R} \delta_R + N_{\delta_A} \delta_A + N_{\delta_Z} \delta_Z + \overbrace{N_{\gamma_4}^{\gamma_4}}^{N.IN} + N_{XZ}^{\dot{p}} \\
 (7) \quad \dot{\phi} &= p + \dot{\psi} \theta / 57.3 \\
 (8) \quad \dot{\theta} &= q + r \phi / 57.3 \\
 (9) \quad \dot{\psi} &= r + q \phi / 57.3
 \end{aligned}$$

UNITS		LEGEND		NOTES
$\theta, \phi, \psi$	- in degrees	I. CR	- Inert. Cross Coup.	All derivatives contain mass or inertia.
$q, p, r$	- in deg/sec	N. IN	- i <sup>sp</sup> or Gust input	
$\dot{q}, \dot{p}, \dot{r}$	- in deg/sec <sup>2</sup>	$\delta_H, \delta_A, \delta_R$	- Aero Contr.	E $\Delta$ mp $\Delta$ : $X_u' = \frac{X_u}{m}$
$u, w, v$	- in ft/sec	$\delta_Y, \delta_X, \delta_Z$	- Reaction Contr.	
$\dot{u}, \dot{w}, \dot{v}$	- in ft/sec <sup>2</sup>	$\delta_W$	- Nozzle Contr.	
All controls in degrees		$\delta_{TC}, \delta_{TL}$	- E mthrot. Con.	

FIGURE III-11

TRANSITION SIMULATION  
LIST OF FUNCTIONS (Not Included  $g \cos \theta$ , etc.)  
(EQUATIONS OF MOTION ONLY)

$X_u(u)$	$f_1(u)$	$M_{\delta_H}$	$f_{17}(u)$	$Z_Y$	$f_{32}(1)$
$X_w$	$f_2(u)$	$N_r$	$f_{18}(u)$	$L_{\delta_X}$	$f_{33}(1)$
$Y_v$	$f_3(u)$	$N_Y$	$f_{19}(u)$	$L_{\delta_Z}$	$f_{34}(1)$
$Y_u(u)$	$f_4(u)$	$N_q$	$f_{20}(u)$	$L_Y$	$f_{35}(1)$
$Y_{\delta_R}$	$f_5(u)$	$N_{\delta_R}$	$f_{21}(u)$	$M_r$	$f_{36}(1)$
$Z_w$	$f_6(u)$	$N_{\delta_A}$	$f_{22}(u)$	$M_{\delta_Y}$	$f_{37}(1)$
$Z_u(u)$	$f_7(u)$	$X_{\delta_W}$	$f_{23}(1)$	$M_{\delta_W}$	$f_{38}(2)$
$Z_{\delta_H}$	$f_8(u)$	$X_{\delta_{TC}}$	$f_{24}(1)$	$M_{\delta_{TL}}$	$f_{39}(2)$
$L_p$	$f_9(u)$	$X_{\delta_{TL}}$	$f_{25}(1)$	$M_{\delta_{TC}}$	$f_{40}(2)$
$L_q$	$f_{10}(u)$	$Y_{\delta_Z}$	$f_{26}(1)$	$M_Y$	$f_{41}(1)$
$L_{\sigma}$	$f_{11}(u, \alpha)$	$Z_{\delta_Y}$	$f_{27}(1)$	$N_{\delta_Z}$	$f_{42}(1)$
$L_{\delta_R}$	$f_{12}(u)$	$Z_{\delta_X}$	$f_{28}(1)$	$N_Y$	$f_{43}(1)$
$L_{\delta_A}$	$f_{13}(u)$	$Z_{\delta_W}$	$f_{29}(1)$		
$M_q$	$f_{14}(u)$	$Z_{\delta_{TC}}$	$f_{30}(1)$		
$M_w$	$f_{15}(u)$	$Z_{\delta_{TL}}$	$f_{31}(1)$		
$M_u(u)$	$f_{16}(u)$				

All others are assumed constant  
(constant multipliers)

$f(1)$  - means function of one variable  
 $f(2)$  - means function of two variables

FIGURE III-12

into the hover. The computer flexibility shall include the "Patch Board" programming approach, so the computer capacity used in the "VSS" mode can be utilized in the "VSSD" mode.

**111-3.7.1.5 COMPUTER FLEXIBILITY.** The computer shall be flexible in respect to "Software" (to be easily reprogrammed). Both **paper** tape and modular replacements must be considered.

**111-3.7.1.6 INPUT/OUTPUT.** The computer shall accept analog input and shall have analog output. The estimated number of computer input/output is as follows:

Inputs (sensors and controls) = **50**

Outputs (after computer is programmed) = **45**

**111-3.7.1.7 COCKPIT CONTROLLER.** Provisions shall be made **for** the evaluation Pilot to control the computer. The switching functions shall be **part** of the VSS Cockpit Control. Preliminary functions are described in VSS Cockpit Controls. The exact function shall be determined during the final design.

**III-3.7.1.8 COMPUTER ERROR.** The computer functions shall not deteriorate the solution of the equations of motion. The overall computer error shall not exceed two percent (static check one percent, dynamic check two percent) when measured from input analog voltage to computer output analog voltage.

**111-3.7.1.9 COMPUTER SPEED.** The computer calculations shall be fast enough to accommodate a simulation **of** any V/STOL jet aircraft during hover and transition stages. In these stages the simulated aircraft rate could be as high as fifty degrees/second, a commanded thrust vector gimbal rate of ninety degrees/second, and some control actuator dynamics of **15-20** cps.

This specification implies that all calculations must be performed with **suffi-**ciently high speed so all computer output signals could appear almost simultaneously. (For example, consider **45** output signals. If signal Number **1** is calculated at  $t_n$ , then calculation of any other signal, such as signal Number **50**, must not be delayed by more than **0.005** second).

**111-3.7.1.10 WEIGHT.** Computer weight shall not exceed 80 pounds.

**III-3.7.2.11 VOLUME.** Total computer volume shall not exceed 3 cubic feet.

**III-3.7.1.12 POWER.** Computer required power shall not exceed 500 watts.

**111-3.7.1.13 COMPUTER PROGRAMMING.** Computer programming instructions shall be supplied with a sample specified problem.

**111-3.7.1.14 DELIVERABLE ITEMS.**

1. Complete digital computer including necessary power supply and A/D and D/A units.
2. Computer ground support.
3. All necessary manuals.
4. All necessary software.

**111-3.7.1.15 COMPUTER MAINTENANCE.** All necessary software and hardware required for computer maintenance shall be supplied. This shall include:

1. Interconnection diagrams and physical specifications.
2. Programming and operating manual.
3. Detail system test procedure.
4. Maintenance Manual.
5. Detailed wiring and circuit drawing.
6. System hardware.

### III-3.7.2 Autopilot

111-3.7.2.1 SCOPE. The autopilot shall perform modes of operations:

1. Conventional autopilot
2. **"Model-Following-Autopilot"**
3. Switching
4. Some signal corrections
5. Signal conditioning

111-3.7.2.2 MODES OF OPERATION DESCRIPTION (See Figure 111-7 and Figure 111-13). There are essentially five modes of operation:

1. Direct
2. Attitude Hold Mode
3. Fly By Wire Direct (FBWD)
4. Variable Stability System (VSS)
5. Variable Stability System Direct (VSSD)

Direct mode applies to the safety pilot only. In this mode, the safety pilot flies the airplane with a conventional mechanical connection between the cockpit controls and a power actuator.

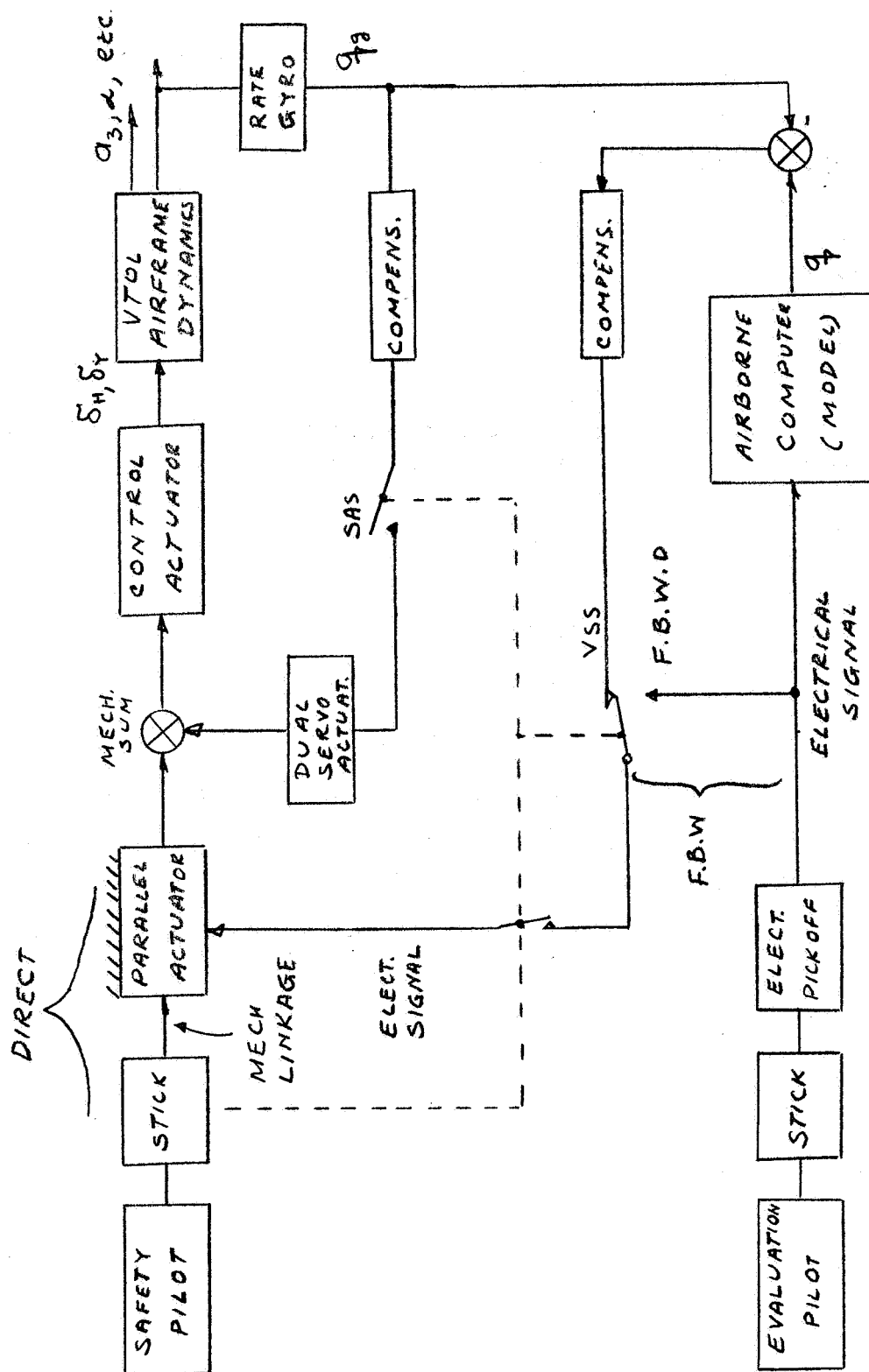


FIGURE III-13. MODES OF OPERATION (PITCH CHANNEL-SIMPLIFIED)

The attitude hold is also a stabilization mode of automatic control of the basic airplane. This mode is intended to hold airplane attitude in either one, or in all three following channels:

1. Pitch
2. Roll
3. Yaw

This mode is needed when the control of the aircraft is being transferred from the safety to the evaluation pilot to fly VSS.

FBWD - Fly by wire direct (FBWD) is an unconventional method of controlling the power actuators. It is a special case of FBW (Fly by Wire). A mechanical connection between a cockpit control and a power actuator is replaced by a "wire" carrying an electrical signal which is proportional to a pilot command. In this mode the airborne computer is bypassed. This mode will enable the evaluation pilot to fly SAS (unlike modes 2 or 4, the autopilot function will be mostly switching).

VSS Mode - VSS is also a special case of FBW, but unlike FBWD, the electrical signals are shaped by the "model" -- the airborne computer.

In this mode the autopilot is the Model-Following-Autopilot. The Model-Following-Autopilot combines aircraft motion parameters so as to provide stability and axis decoupling for the basic VTOL aircraft. In effect this will result in an uncoupled and responsive airframe to follow the model aircraft motions which are commanded.

The autopilot closes feedback loops around the basic VTOL airplane. The incoming signals from airborne computer (a "model" or simulated VTOL) act as steering commands. In this mode, up to five individual channels can be engaged. These channels are:

1. Pitch
2. Roll
3. Yaw
4. Throttle
5. Vector

The throttle channel has two switches which can control either lift engine throttles, or lift/cruise engine throttles, or both.

VSSD is the "Patch Board" of the airborne computer. (See Figure III-7.) The pilot commands here are "patched up" with the sensor signals and always bypass the Equations of Motion, and go directly to the actuators. This mode depends on a programmer's skill to use the proper feedback gains and signs.

Figure III-14 illustrates the modes of operation and **major** assumptions of this requirement. As a general rule, the evaluation pilot will always fly the airplane. There are exceptions to this rule. The safety pilot will fly the airplane during new pilot checkout and during airplane pre-delivery flight test. During emergency, the safety pilot can overpower VSS or autopilot operation.

**III-3.7.2.3 SWITCHING LOGIC.** The autopilot shall perform switching function logic, such as from SAS to Attitude Hold, from Attitude to VSS, from safety pilot to evaluation pilot, etc.

**III-3.7.2.3.1 Safety & Switching.** Switching from VSS to SAS shall be made safely, even when VSS is overpowered. All VSS commands shall synchronize the safety pilot stick motion with both external controls.

Switching from SAS into VSS or from VSS into SAS shall be accomplished with very small transients. Electrically engaging or disengaging of all or any **VSS** actuator shall be only after the actuator is trimmed with all input commands active.

**111-3.7.2.3.2 Autopilot Switching Requirements.** The requirement for inflight switching (normal flight) is outlined in Figure 111-15.

**III-3.7.2.4 AUTOPILOT WEIGHT.** The autopilot weight shall not exceed 40 pounds.

**III-3.7.2.5 AUTOPILOT DIMENSIONS.** The autopilot dimensions shall be within 3/8 ATR.

### **III-3.7.3 VSS Cockpit Controller**

The VSS cockpit controller shall command the VSS function control from the front cockpit by the evaluation pilot. The following functions are available.

**I. CONDITIONS ASSUMED IN V/STOL REQUIREMENT**

Type of Flying	Pilot	Mode of Operation	SAS	Note
Normal	Evaluation	F. B. W. D.	On	
	Safety	Stand By		
Normal	Evaluation	VSS or VSSD	Off	Any Stability F. B. are Mechanized in VSS
	Safety	Stand By		
Normal	Evaluation	Stand By	On	Flight Test or Training
	Safety	Direct		
Emerg.	Evaluation	VSS or VSSD	On	VSS Failure
	Safety	Direct - VSS or VSSD is overpowered		
Emerg.	Evaluation	F. B. W. D.	Off	SAS Failure
	Safety	Direct - F. B. W. D. overpowered		

**II. CONDITIONS NOT CONSIDERED BY V/STOL REQUIREMENT**

Type of Flying	Pilot	Mode of Operation	SAS	Note
Normal	Evaluation	F. B. W. D.	Off	
	Safety	Stand By		
Normal	Evaluation	VSS	On	
	Safety	Stand By		

FIGURE III-14. MODES OF OPERATIONS - ASSUMPTIONS

INITIAL MODE OF CONTROL	CONDITIONS OF INITIAL MODE	DESCRIPTION OF SWITCHING OPERATION (From Initial to Final Mode)	FINAL MODE OF CONTROL	CONDITIONS OF FINAL MODE
SAFETY PILOT FLYING (SAS ON)	1. SAS on 2. E. V. Controls Off 3. Autopilot Off 4. VSS Act. Disengaged	1. Safety Pilot Holds Airplane in Straight and Level Unaccelerated Flight 2. E. V. Pilot Switches E. V. Controls on F. B. W. D. to VSS Act. 3. E. V. Pilot Trims E. V. Controls 4. E. V. Pilot Engages VSS Actuators	EVALUATION PILOT F. B. W. D. (SAS ON)	1. E. V. Controls on F. B. W. D. 2. SAS On 3. VSS Act. Engaged 4. Autopilot Off
SAFETY PILOT FLYING (SAS ON)	(See Above)	1. Safety Pilot Holds Airplane in Straight and Level Unaccelerated Flight 2. E. V. Pilot Closes Autopilot Loops to VSS Actuators 3. E. V. Pilot Engages VSS Actuators; Engagement of VSS Actuators with Autopilot Loop Closed Also	ATTITUDE HOLD (AUTOPILOT)	1. E. V. Controls Off 2. SAS Off 3. VSS Act. Engaged 4. Autopilot On
ATTITUDE HOLD (AUTOPILOT)	1. E. V. Controls Off 2. SAS Off 3. VSS Act. Engaged 4. Autopilot On	1. E. V. Pilot Sets All Initial Conditions into Computer using Measured $U_0$ , $\alpha$ , $W_0$ , etc 2. E. V. Pilot Trims E. V. Controls and Adjusts Voltage Output on E. V. Controls to Zero 3. E. V. Pilot Switches E. V. Controls to VSS Computer and Switches Computer to Operate 4. E. V. Pilot Fades on Computer Output to VSS	EVALUATION PILOT VSS (SAS OFF)	1. E. V. Controls to VSS Computer On 2. SAS Off 3. Autopilot On 4. VSS Autopilot Command On
EVALUATION PILOT VSS (SAS OFF)	1. E. V. Controls to VSS Computer On 2. SAS Off 3. Autopilot On 4. VSS Autopilot Command On	1. E. V. Pilot Holds Airplane in Straight and Level Unaccelerated Flight 2. E. V. Pilot Fades Off Computer Output From VSS Actuators 3. E. V. Pilot Disengages VSS Actuators; Disengagement of VSS Act. With Autopilot Loop Closed Also	SAFETY PILOT FLYING (SAS ON)	1. SAS On 2. E. V. Controls Off 3. Autopilot Off 4. VSS Act. Disengaged
EVALUATION PILOT F. B. W. D. (SAS ON)	1. E. V. Controls On F. B. W. D. 2. SAS On 3. VSS Act. Engaged 4. Autopilot Off	1. E. V. Pilot Holds Airplane in Straight and Level Unaccelerated Flight 2. Safety Pilot Trims Safety Pilot's Controls For Zero Force on Feel System 3. E. V. Pilot Disengages VSS Actuators	SAFETY PILOT FLYING (SAS ON)	(See Above)
ATTITUDE HOLD (AUTOPILOT)	1. E. V. Controls Off 2. SAS Off 3. VSS Act. Engaged 4. Autopilot On	1. Safety Pilot Trims Out Safety Pilot's Controls for Zero Force on Feel System 2. E. V. Pilot Disengages VSS Actuators; Disengagement of VSS Act. with Autopilot Loop Closed Also Turns SAS On	SAFETY PILOT FLYING (SAS ON)	(See Above)
EVALUATION PILOT VSS (SAS OFF)	1. E. V. Controls To VSS Computer On 2. SAS Off 3. Autopilot On 4. VSS Autopilot Command On	1. E. V. Pilot Holds Airplane in Straight and Level Unaccelerated Flight 2. E. V. Pilot Fades Off Computer Output From VSS Actuators 3. E. V. Pilot Trims E. V. Controls for Zero Output Voltage and Desired Control Position 4. E. V. Pilot Switches E. V. Controls on F. B. W. D. to VSS Actuators 5. E. V. Pilot Fades Out Autopilot Loop to VSS Actuators; This Action Turns SAS On	EVALUATION PILOT F. B. W. D. (SAS ON)	1. E. V. Controls On F. B. W. D. 2. SAS On 3. VSS Act. Engaged 4. Autopilot Off

FIGURE III-15. NORMAL INFLIGHT SWITCHING REQUIREMENT (PITCH, ROLL, OR YAW ONLY)

1. Mode Selector. This switch has two positions, VSS and VSSD. When in VSSD position, the command signals bypass the equations of motion, which implies that the airplane is ready to fly in VSSD mode. VSS position implies readiness for VSS mode. Only after the VSS actuator switch is put into "ON" position along with other switches, can the evaluation pilot fly VSS or VSSD mode.
2. VSS Actuator Engagement Switch. This switch will actuate all clutches in the parallel VSS actuators.
3. Null Indicator - Optional for evaluation pilot - used during switching from the safety pilot controls to the evaluation pilot controls. This indicator will indicate the pitch stick relative positions.
4. FBWD Switch. This switch in ON position, and the VSS actuator clutch switch in ON position, will put the aircraft into FBWD mode.
5. Attitude Hold Switch. This switch in ON position and the VSS actuator clutch switch in ON position will put the aircraft into attitude hold mode.
6. The computer operation switches are RESET and COMPUTE.
7. The initial condition pots will set the initial conditions into the computer.
8. The flight condition select will change the flight condition program in the computer.
9. The VSS authority control will change the signal authority from thirty percent to one hundred percent. There are ~~six~~ independent controls.
10. VSS mode engagement switches. There are five individual switches: pitch, yaw, roll, throttle, and vector. These switches will put the aircraft in VSS mode only from the attitude mode, which implies that it is impossible to go directly from Direct Mode to VSS Mode, or from FBWD\* to VSS. For example, when the VSS pitch switch is on, the aircraft will fly VSS mode in pitch channel only, roll and yaw in attitude hold, throttle and vectors in FBWD.

III-3.7.3.1 WEIGHT. The VSS controller weight shall not exceed 10 pounds.

111-3.7.3.2 DIMENSIONS. The VSS controller dimensions shall not exceed 6 inches by 6 inches by 8 inches.

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\*FBWD applies to Pitch, Roll, or Yaw; throttle or vector channels do not have attitude mode.

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### **111-3.8 CONTROL SYSTEM INTERFACE**

The VSS shall interface with the control system as discussed in **111-3.8.1**, and in **III-3.8.2**.

#### **III-3.8.1 Rotational Control (Pitch, Roll, Yaw) - Description**

The block diagram which is typical for pitch, roll, or yaw channels is shown in Figure **III-16**. This figure indicates how the autopilot is functionally related to the air-borne computer in the VSS mode. A mechanical implementation is shown on Figure **111-17**.

Safety requirements and multiple input capability are the most important factors which shall dominate the control system. Precautions shall be taken to make each channel responsive (pitch, roll, and yaw).

The control system shall have frequency response for each channel (from cockpit controls to external control\*, or from VSS computer output to external control\*) which can be approximated by third order lag, with time constant,  $\tau = .032$  sec, and with natural frequency,  $f_n = 5$  cps, and damping ratio,  $\zeta = .2$ .

During the transition phase, the airplane moment is controlled by a combination of an aerodynamic control surface input, and reaction control jets. These two kinds of external airplane controls can be controlled either from the front cockpit controls (evaluation pilot) or from aft cockpit controls (safety pilot). During FBWD or Direct mode, the pilot inputs are combined with the SAS inputs.

With these multiple input capabilities several combinations of signals may be assumed; however, only systems which reflect requirements illustrated by the conceptual diagram of Figure **111-18** are to be considered.

The concept is a simple, easily mechanized control system. The VSS electrical signal will energize the parallel actuator, which then will move simultaneously the safety pilot stick, and both external controls. As Figure **III-18** shows, the stabilizer is geared to the reaction control position. The gearing can be fixed, or programmed to respond to a slowly changing variable (trim).

#### **III-3.8.2 Translational Control (Throttle and Vector) - Description**

The Translational Control System consists of two separate channels: the throttle control, and the vector control. Each pilot is supplied with identical cockpit controls, two throttle controls and only one vector control. One throttle control is for the two

\*External control is reaction nozzle position, rudder position, etc.

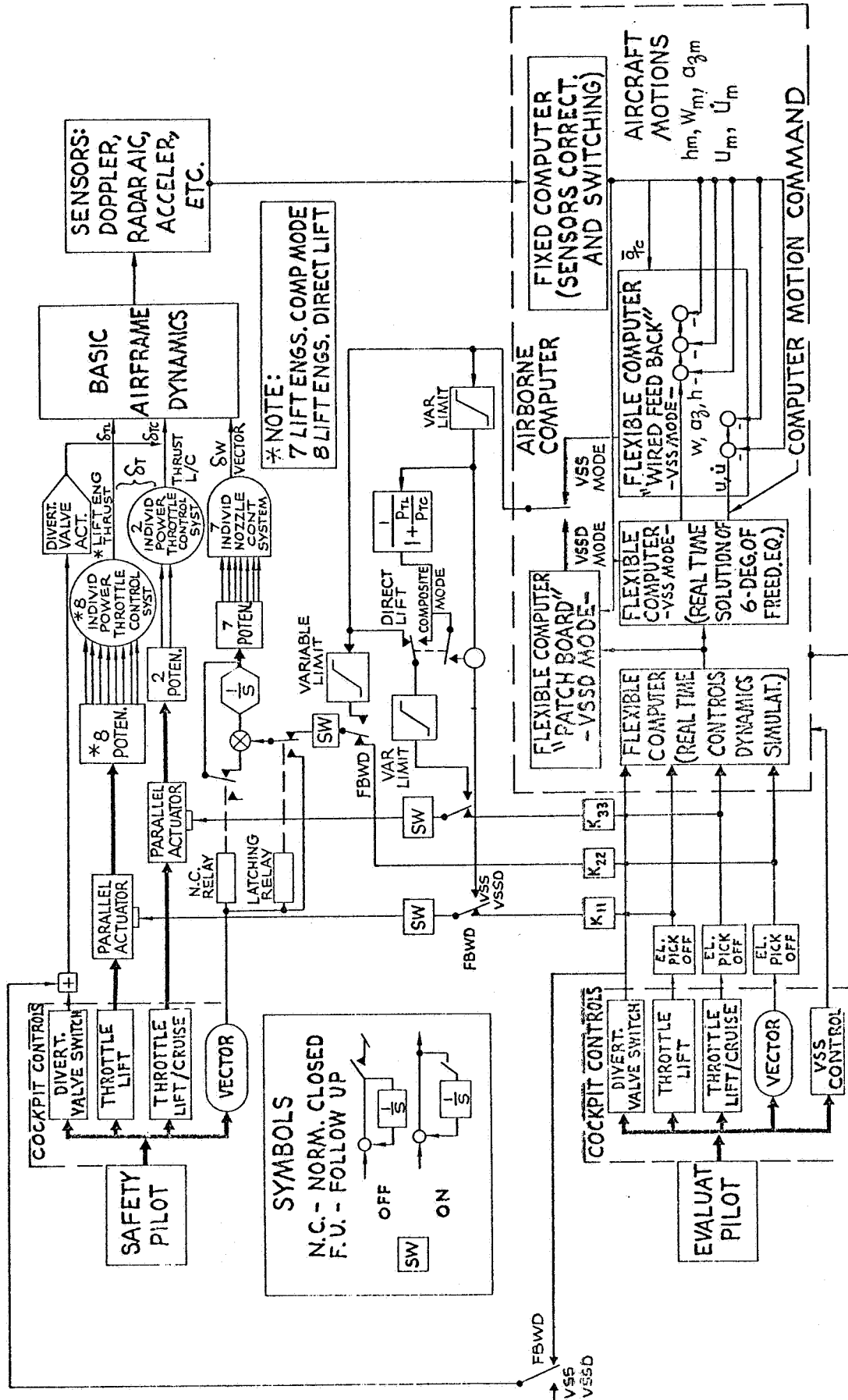


FIGURE III-13 USE BLOCK DIAGRAM (THROTTLE AND VECTOR)



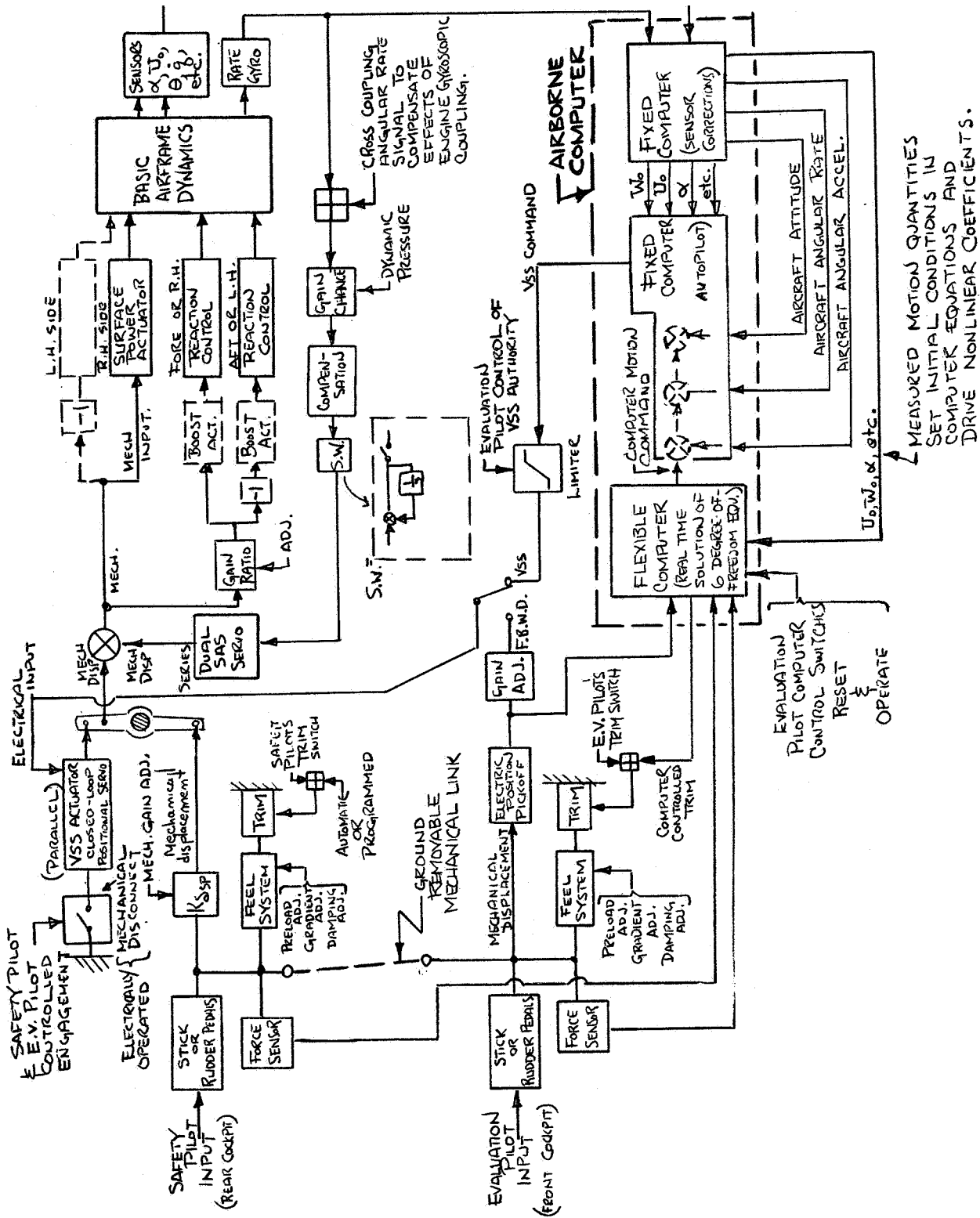


FIGURE III-18. PITCH, ROLL, OR YAW CONCEPTUAL DIAGRAM

lift/cruise engines, and another control for all lift engines. Safety and evaluation pilot cockpit controls are mechanically disconnected from each other under normal flight conditions. The evaluation pilot electrical signals can be fed into the computer for VSS mode, or bypassed for FBWD mode (see Figure III-19).

In the throttle channels, the pickoff signals or the VSS computer command can control the parallel actuators so the safety pilot's controls always move. The safety pilot is in standby during normal flight; however, he can always overpower the parallel VSS actuator at any time.

The vector control channel is different from the throttle. The pick-off signals or computer output do not move the evaluation pilot control. Only a cockpit display will indicate nozzle-vector position. However, the safety pilot can always override the evaluation pilot. A commanded vector input will also energize a latching relay, and immediately open FBWD or VSS outputs.

The lift engines will be equipped with movable nozzles and nozzle servo actuators supplied by the engine manufacturer.

The principle of VSS operation in the translational degrees of freedom is the same as for the pitch channel. Instead of pitch rate, two translational velocities of the basic airplane will be used to match the simulated airplane velocities,  $u_c$ ,  $w_c$ . The evaluation pilot's input first will be shaped by a "model", the airborne computer, and then compared to the sensed velocities,  $u_m$ ,  $w_m$ . The error signals, between the model and the sensed velocities, then will be used to command an incremental change in nozzle position and in throttle position. This command, if idealized, is that which will produce a time program of  $x$  and  $z$  forces as necessary to match actual aircraft velocities,  $u$  and  $w$ , with those of the simulated airplane,  $u_c$  and  $w_c$ .

The VSS translational control requires sufficient flexibility for operation in either of two modes: direct lift mode or composite mode. The control mechanization shall be capable of accomplishing this by a simple switch position.

In the direct lift mode, the lift engines provide all the necessary engine lift forces through hover and transition; in this mode, the two lift/cruise engines supply forward thrust only.

In the composite mode, the lift engines plus the two lift/cruise engines with downward vectored thrust, provide all necessary engine lift during hover, and during transition.

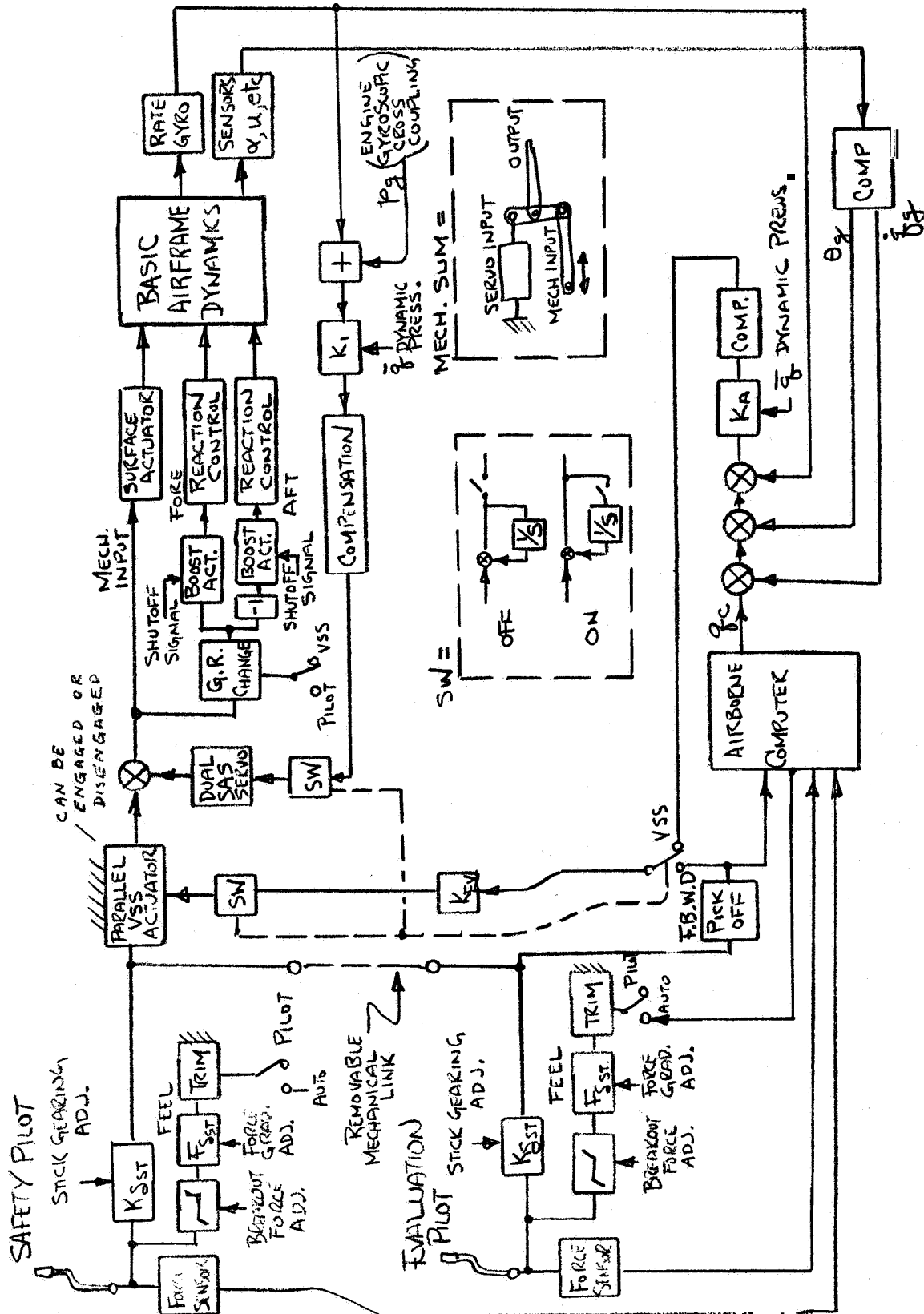


FIGURE III-19. PITCH CHANNEL CONCEPT

The thrust from all lift engines can be vectored (by positioning all nozzles) 15 degrees forward and 28 degrees aft. The expected maximum rate of thrust vectoring is 90 degrees/second.

The safety or the evaluation pilot can fly the basic airplane independently, take off and land, however, the safety pilot can always overpower the evaluation pilot. When the evaluation pilot is flying, except for the vector and diverter valves, all the safety pilot cockpit controls are moving. The vector and diverter valve position, however, shall always be displayed to the safety pilot.

The vector and the throttle channels in each cockpit shall have one vector control, one diverter valve control, and two throttles controls — one for all lift and one for all lift/cruise engines.

The control system frequency response shall be as follows:

1. Vector channel: 2<sup>nd</sup> order lag with natural frequency,  $f_n = 8$  cps and damping ratio,  $\zeta$ , between .5 and 1
2. Throttle Channel:
  - a) The G. E. engine is expected to act as a first order lag with a time constant,  $\tau = .2$  second
  - b) The throttle control: 3<sup>rd</sup> order lag with time constant = .05 second, and natural frequency  $f_n = 3.5$  cps. Damping ratio,  $\zeta$ , between .3 and .8.

### III-3.9 SENSORS - CHARACTERISTICS AND LOCATION

#### III-3.9.1 Dynamic Characteristics

The VSS shall use sensors with dynamic characteristics equivalent, or superior to those listed in Figure III-20.

#### III-3.9.2 Sensor Error

The VSS shall use sensors with errors not to exceed those listed in Figure III-20.

#### III-3.9.3 Sensor Locations

The basic sensor locations in the airplane shall be within areas listed in Figure III-20.

SENSOR	CHARACTERISTIC	O	ON
RATE GYRO	Natural Freq. $= f = 45$ cps; damping $\zeta = .7$ Hysteresis $= \pm .15\%$ ; Resolution $= .01$ Deg/Sec.	Equipment Bay	c. g.
ATTITUDE GYRO	Response: Over 50 cps Error: Vertical $= 1/4$ Deg.; Pick off $= 1/4$ Deg.	Nose Compartment	
DOPPLER	First order lag: $\tau = .05$ Sec. Deadzone $= \pm .25$ KN.; $1\sigma$ Error $= .1\% + .1$ KN	Nose Compartment	
RADAR ALTIMETER	First order lag: $\tau = .5$ Sec. Error: Altitude $= 1$ Ft. $+ 1\%$ . rate 1 ft/sec. $+ 3\%$	Nose Compartment	Antennas: Fore and Aft
LINEAR ACCELERATION (Force F. B.)	Natural Freq. $f_n = 100$ cps; damping $\zeta = .8$ Hysteresis $= .1\%$ ; Resolution $= .1\%$ ; Deadzone $= .1\%$	Near C. G.	
ANGULAR ACCELERATION (Force F. B.)	Natural Freq. $f_n = 80$ cps; damping $= .5$ Hysteresis $= .1\%$ ; Resolution $= .1\%$ ; Deadzone $= .1\%$	Near C. G.	
$\alpha$ & $\beta$ (Conv.) Angle of Attack and Sideslip	Natural Freq. $f_n = 3$ cps (For use above 60 KN) Error: $1/4$ Deg.	Boom	
Aeroflex System (Wind Velocity Measurement)	Response limited by F. B. Servo System Deadzone $= .2$ KN., Accuracy $.5$ KN $+ 5\%$	Nose (Below Boom)	
Gyro Compass GE SR-3	Natural Freq. $f_n = 15$ cps Null $= .15$ Deg., Pick off $= .233$	Aft Safety Pilot Bulk Head	

FIGURE III-20. SAE/WS NSOR#

### III-4.0 GROUND CHECKOUT EQUIPMENT

#### 111-4.1 TEST CONSOLE - SCOPE

For ground checkout of the SAS and VSS prior to flight, a test console and test equipment shall be provided. This equipment shall introduce simulated control transducer signals into the SAS and VSS flight control system, in a manner to verify that the system is functioning properly. Analysis and location of system problems, should they occur, shall be provided by this same equipment.

#### III-4.2 TEST CONSOLE TYPE

The aircraft ground checkout console shall be of the upright cabinet type. For ease of relocation, wheels shall be provided as an integral part of the unit. Limited storage space for various test equipment and cables shall be provided in the console.

#### III-4.3 TEST CONSOLE EQUIPMENT

For waveform and signal monitoring, a Tektronix Type RM 564 oscilloscope with a Type 3A3 Dual-Trace Amplifier and a Type 2B67 Time-Base Unit shall be mounted in the console assembly. A Weston Model DA410 Frequency Response Analyzer shall be provided to simulate sensor inputs and display system response. An accurate Digital Voltmeter and a low frequency function generator and correlator are incorporated within the DA410 analyzer.

##### 111-4.3.1 VSS Computer

The Test Console shall have provisions to check airborne computer. Both digital and analog signals shall be checked.

##### 111-4.3.2 Provisions for Recording

A patchboard system or equivalent shall be provided that has the capability of handling selection of input/output function connections as required, plus a receptacle to accommodate a strip chart recorder. The patchboard shall also provide mode functions as required.

All required ground recorder tie-in receptacles, ship interface receptacles and cables, and the various annunciator lights and control switches shall be provided according to the final design.

#### **III-4.4 MANUALS**

An operations manual of instructions covering all aspects of the console operating procedures including details of construction, parts identification and wiring shall be provided.

#### **III-4.5 SPECIAL EQUIPMENT**

Any items of special equipment needed to reprogram, checkout, or maintain the airborne digital computer shall be provided. Packaging of this equipment shall be consistent with handling and use encountered in flight line operations.

Manuals covering all details of indoctrination, operating procedures, maintenance, programming and checkout shall be provided.

#### **111-4.6 SAS CHECKOUT**

The test console shall have provisions to check SAS system alone, including all redundant loops.

#### **111-4.7 INTERFACE SAS AND VSS**

The test console shall have provisions to check safety logics between VSS and SAS systems.

## APPENDIX IV

### INTERCHANGEABLE AND REPLACEABLE COMPONENTS

The following components **of** the aircraft shall be interchangeable or replaceable as designated by the notations "I" and "R" respectively:

Wing Outer Panels (L/R)	R
Flap Assemblies (L/R)	R
Aileron Assemblies	R
Tip Assemblies, Wing	R
Horizontal Tail	R
Rudder	R
Main Landing Gear	I
Shock Absorbers	I
Drag Links	I
Nose Landing Gear	I
Shock Absorber	I
Drag Link	I
Ejection Seats	I
Instrument Panel	R
Direction Control Pedals	R
Control Stick	R
Propulsion Thrust Control Assembly	I
Forward Pitch/Yaw Nozzles	R
Rear Pitch/Yaw Nozzles	R
Wing Tip Roll Nozzles	R

Engines, Equipped for Installation	I
Diverter Valves	I
Exhaust Ducting	R
Induction Doors	R
Exhaust <b>Doors</b>	R
Landing Gear Doors	R
Engine Section Access Doors	R
Fuselage Access <b>Doors</b>	R
Wing Access <b>Doors</b>	R
Control System Linkages	R
Stabilization Augmentation System Subassemblies	R
Variable Stability System Subassemblies	R
Bleed System Duct Subassemblies	R
Windshield	R
<b>Canopy</b>	R
Actuators, Main Gear	I
Nose Gear	I
Flap	I
Aileron	I
Elevator	I
Rudder	I
Feel	I
Induction Doors	I
Exhaust Doors	I
Diverter Valves	I
Hydraulic System Components (Except Lines)	I

Hydraulic System Line Subassemblies	<b>R</b>
Electrical System Components (Except Wire Bundles)	<b>I</b>
Electrical System Wire Bundles	<b>R</b>
Accessory Drive Units	<b>I</b>
Oxygen System Components	<b>I</b>
Fuel System Components (Except Lines)	<b>I</b>
Fuel System Line Subassemblies	<b>R</b>

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